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I4.0 Strategy and Policy Integration in The German Machining Industry

Master Thesis

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Abbreviations

I4.0	Industrie 4.0
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy)
IoT	Internet of Things
IIoT	The Industrial Internet of Things
M&Es	Machine and Equipment Industry
SMEs	Small and Medium-Sized Enterprises
KPIs	Key Performance Indicators
RAMI4.0	Reference Architecture Model for Industrie 4.0
ZVEI	German Electrical and Electronic Manufacturers' Association
SIMMI 4.0	System Integration Maturity Model Industry 4.0
ICT	Information and Communication Technologies

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1 The Emergence of Industrie 4.0 a New Means of Manufacturing

Industrie 4.0 (I4.0) refers to the fourth industrial revolution, which is currently in the phase of implementation (Schwab, 2016). The fourth industrial revolution is different from the previous three industrial revolutions as it is the first industrial revolution to be planned by politicians and industrialists which sought to control the direction of the revolution through specific funding and research policies; which include the development of ministries to promote and guide the direction, alongside academia, the public and private sector (Schwab, 2016).

An industrial revolution is a period throughout history in which the manufacturing industry of a country is disturbed in a way that directly transforms the entity of the country, causing implications culturally, economically, and the process of manufacturing. There have been periods in which industrial revolutions have taken place throughout modern history, and currently, the fourth industrial revolution is being undertaken. *The First Industrial Revolution (1784 - 1870)* began in Great Britain, which is attributed to the mass adoption of mechanisation, steam and waterpower in manufacturing processes (Horváth, 2018). *The Second Industrial Revolution (1870 – 1969)* commenced with the adoption and integration of mass production, electrical power, and the implementation of the assembly line in manufacturing processes which lasted until 1969 (ibid). The integration of automated production, electronics and computers into the manufacturing processes began T*he Third Industrial Revolution (1969 – 2013)* (ibid). *The Fourth Industrial Revolution (2013 – Present),* which began in Germany and which this paper will focus on addressing, is commonly attributed to the adoption of artificial intelligence (AI), big data, IoT (Internet of Things), and robotics into the manufacturing process (ibid). The progression of industrial revolutions throughout modern history, which has eventually led to the current industrial revolution, which is the fourth, can be illustrated in Figure 1.

The fourth Industrial revolution has been at the forefront of manufacturing discussion since 2011. The implications of its arrival on the manufacturing process will have significant implications on numerous different aspects of society, such as employment, political influence, and economic capabilities. To secure a nation's manufacturing future, politicians have identified the significance of ensuring a smooth transition into the fourth industrial revolution to either maintain their current global position or better it. Global manufacturing giants such as China, the United States, Japan, and Germany have all implemented policies surrounding I4.0 within their nation to secure global influence in the manufacturing sector (Kagermann, Anderl, Gausemeier, Schuh, Wahlster, 2016). At the same time, countries such as Mexico, Italy, and Singapore have implemented policies

to advance their current global manufacturing position (Hocken, Harland, Bleider & Romero, 2018; see also Singapore Economic Development Board, 2017). Thus, the fourth industrial revolution has been identified by policymakers globally as a significant starting point to address to ensure and safeguard their national manufacturing capabilities.

The fourth Industrial revolution does not exclusively focus on the technical aspects within the manufacturing process, as additionally, it addresses the business process of manufacturing enterprises. Therefore, the fourth industrial revolution is a revolution that disrupts the business process and the technology utilised within the processes, which thus requires an integrated approach of the two. In order to secure the yield benefits of I4.0, an enterprise must adapt its business process to allow contestant information exchange between the physical business world and that of the virtual technological world. This process includes adapting businesses processes to incorporate an agile approach both vertically and horizontally to include direct information exchange from the technological equipment.

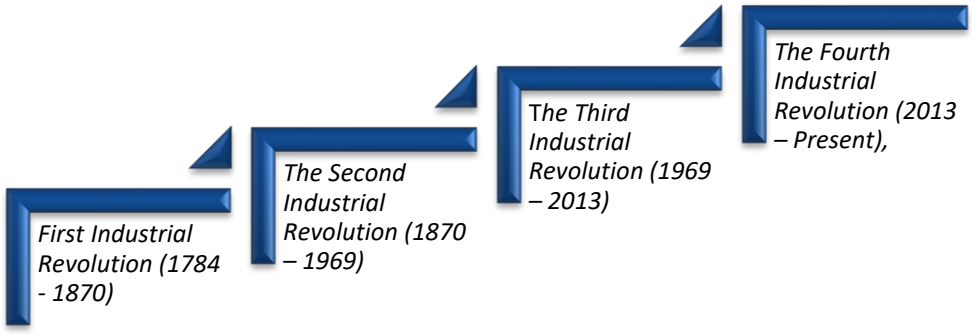

Figure 1 History of Industrial Revolutions

1.1 IOT AND IIOT

The Internet of Things (IoT) is a term that refers to "interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data" (Oxford University Press, 2020). IoT is related to Industrie 4.0 as it is an enabler of I4.0 functions, as the internet allows for the transmission of data through interconnected computing devices throughout the factory, organisation, and customers, which is related to intelligent manufacturing. Smart factories or digital factories transform the operations by applying IoT, which enables data to be transferred transparently throughout the enterprise across all levels of operation, which is collected through sensors to adapt and monitor operations and resources (Alcácer & Cruz-Machado, 2019). This transformation in the manufacturing process has allowed for manufacturing to be conducted

transparently and effectively. The autonomous transparent sharing and communication of data has allowed for every aspect of manufacturing to be monitored and utilised to the fullest extent of its capabilities holistically along the value chain, which is the definition of Industrie 4.0 capabilities in manufacturing (Smit, Kreutzer, Moeller, Carlber, 2016). IoT is only present within the fourth industrial revolution, as it builds upon the previous third industrial revolution's use of electronics and IT to achieve autonomous manufacturing, which then allows for the construction of cyber-physical systems.

The Industrial Internet of Things (IIoT) differs from IoT due to its perceived focus on the industrial and manufacturing components of smart devices to support the manufacturing process. In contrast, IoT focuses on the consumer use of smart products. Both definitions can be utilised when referring to I4.0; however, IIoT is utilised during the manufacturing process, and IoT can be utilised when referring to the final consumer use of a product that might still be connected since the manufacturing process began to provide quality support, or data for consumer usage (McKnight, 2017).

I4.0 has disrupted the modern manufacturing process, which has now required enterprises to incorporate digital capabilities through IIoT in order to stay competitive domestically and globally. Digital transformation and alignment with business and IT processes are required in I4.0 to attain a competitive advantage in manufacturing. The demand for an integrated manufacturing process with digital compatibilities has become not exclusively a concern for manufacturing enterprises but, moreover, the governments of the countries in which these enterprises belong. The Federal Republic of Germany has become a leading player in ensuring I4.0 transformation in Germany, the European Union, and its trading partners. I4.0 transformation is regarded as a primary objective of the federal government to ensure that the German economy remains a leading and dominant player. The result of a slow I4.0 transformation in Germany could potentially cause German manufacturing and enterprises to fall behind and no longer hold their internationally recognised position as a leader (Horst & Santiago, 2018). The loss of a leading global position in manufacturing would severely hinder Germany's influence internationally and has become a crucial focal point in German High-Tech Strategy to ensure that the federal government can continuously maintain a leading role through German manufacturing.

1.2 Application and IT Layer of I4.0

The Application and IT layer, which will be the focus of this research, can be best defined utilising the TOGAF framework for enterprise architecture. The Open Group (2018) developed the TOGAF framework to address the As-Is and To-Be status of an organisation or enterprise to perform an enterprise architecture transformation and

management, to re-design the processes throughout, both physically and digitally (Visual Paradigm, n.d.). The application layer which the paper will refer to will be in relation to Phase C, which is *Information System Architecture*, and the IT layer will refer to Phase D, which is *Technology Architecture* in TOGAF (The Open Group, 2018). The phases are presented in Figure 2, which provides the TOGAF framework in relation to the core layers, implementation & migration, and strategy & motivation of an enterprise which are modelling layer language from ArchiMate 3.0 for designing an enterprise transformation (Visual Paradigm, n.d.). The breakdown of enterprise architecture transformation into core functions of an enterprise for modelling serves to clarify which layers this paper will address.

The application layer of an enterprise refers to the software applications which serve the business functions and processes and are served by software (Wijnhoven, 2009). The application layer is the layer that connects the relationship between the business processes and physical world with that of the Technology (IT) Layer (The Open Group, 2018). The application layer within enterprises is the systems, applications, and programs that are operated to support the conduction of the business process and are the first line of the cyber world transitioning from physical to cyber (The Open Group, 2018) Therefore, these applications are the focus of the research and will be evaluated to determine how far integrated they are into the entirety of the business process from B2C (business to consumer).

The Technology Layer and Physical Elements layer, or sometimes referred to as the IT Layer, will be referred to as the IT landscape within this paper as it will incorporate the two layers to address the overall IT landscape of the enterprise. The IT Landscape of an enterprise refers to the technology and hardware required to operate the applications in the application layer (The Open Group, 2018). These can relate to infrastructure services such as storage and processing. The IT Landscape is the supporting physical products within the physical world utilised to support the cyber applications in the application layer to support further and enhance the physical businesses operations. This layer offers services needed to operate applications, which are realised by information and communication technologies (ICTs), devices and system software (Wijnhoven, 2009).

Together the Application Layer and IT landscape operate in conjunction to support the overall Business Layer and its operations (Wijnhoven, 2009). Therefore, in order to investigate deeply into the adoption of I4.0, this research will focus on assessing the I4.0 transformation within the IT landscape and Application layer. An investigation into these layers will enable the possibility to determine the deeply embedded challenges within the

ICT and applications that support the *small and medium enterprise's* (SMEs) overall operations being analysed.

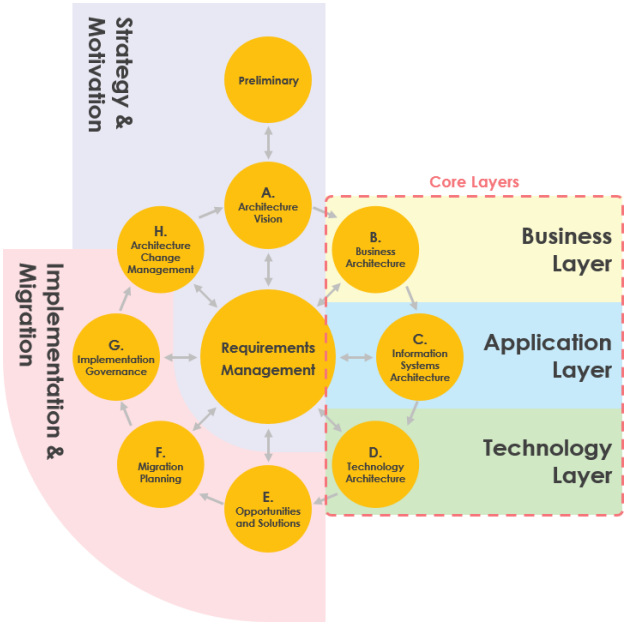

Figure 2 TOGAF (Visual Paradigm, n.d.)

1.3 Research Motivation

The significance of this research can be best illustrated in Figure 3, which represents how each attribute was selected to be investigated due to its overall relationship with I4.0. These relationships indicate the overall overlapping relations between I4.0 and the federal government and why selected focuses were chosen to be investigated within this research.

In 2011 at the Hannover Fair, the federal government of Germany, alongside academics, and enterprises launched what is regarded as Industrie 4.0 to the public, in which the government sought to ensure digital transformation within the manufacturing industry in Germany (Pfeiffer, 2017). Industrie 4.0 is meant to disrupt the current economy within Germany. Business and information technology is required to align throughout the businesses processes; however, investigating the adoption of I4.0 throughout the entirety of the German economy is not feasible to be conducted within this research. Therefore, this research aims to investigate what can be attributed as the heart of the German economy in order to investigate the I4.0 transformation.

This research aims to provide policy recommendations to the federal government on how to better support I4.0 adoption in Germany based upon current challenges and successes that have been observed and concluded through a maturity index. Therefore, the federal government of Germany is depicted on the outer circle of Figure 3 to

demonstrate the less specific investigation of the research, yet at the same time, the actor to whom the research is designed to be provided.

Industrie 4.0 is placed on the seconded circle from the centre to demonstrate that the federal government aims to impact the development and implementation of I4.0 progression within the German economy, which is the circle below. I4.0 demonstrates a relationship between the federal government and the German economy, in which there is a push and pull factor of the driving of the adoption progression and the impact on economic production.

The German economy, as stated prior is impacted by the progression of I4.0, which aims to disrupt businesses processes through digitalisation to ensure a continuously competitive German economy (BMWi, 2016a). However, the German economy possesses an essential relationship with SMEs, which are the bulk of the German economy (BMWi, 2017). Therefore, the successful adoption of I4.0 is paramount for German policymakers in the federal government and industries in technology and manufacturing. Through ensuring the successful adoption of I4.0 in relation to the federal government's expectations, which is supported through federal policy, the aim is to support SMEs. SMEs are additionally known as the Mittelstand, which account for 99.6 per cent of German businesses (BMWi, 2017). Due to SME's accounting for most enterprises within the German economy, it is crucial to ensure that I4.0 policy considers the challenges and successes they are facing; thus, effective I4.0 adoption in SME's will support the overall success of the state and economy.

At the very heart of Figure 3, the German *Machine and Equipment industry* (M&Es) are located. M&Es are positioned at the centre of the relationship figure as it is one of the industries in Germany in which SMEs are heavily concentrated, in which 90 per cent of the M&E industry are SMEs (GTAI, 2019). Furthermore, M&Es contribute significantly to many other industries within the German economy due to their production, providing direct service to other industry fields such as aerospace and automotive to produce parts and components for assembly (GTAI, 2019). M&Es can be regarded as an industry sector that is directly tied to many other sectors through supporting operations. As M&Es are concentrated by SMEs and are a supporting industry to other sectors of the German economy, the successful adoption of I4.0 in the M&Es sector is crucial in ensuring Germany's role as a leading manufacturing nation.

As mentioned, prior, it is not feasible to investigate the entity of the German economy, which is implementing Industrie 4.0, to determine the overall successes and challenges within this research. Therefore, this research is investing in the M&Es industry due to their relationship with other factors which are considered throughout. The investigation

of I4.0 adoption within German SMEs, which are M&Es, will provide a snapshot of the current challenges which are being faced within I4.0 adoption. Through investigating this section of industry of the German economy, this paper seeks to provide an isolated investigation into what can be referred to as the heart of the German economy to determine how to better develop federal government policy in Germany to support I4.0 adoption. As the research conducted within this paper is exploratory, it cannot determine every challenge and success currently being faced in German industry. However, the paper expects that by conducting research into an industry that is heavily aligned and integrated with other sectors, it will be possible to identify factors to aid future policy development in Germany for I4.0 adoption in manufacturing.

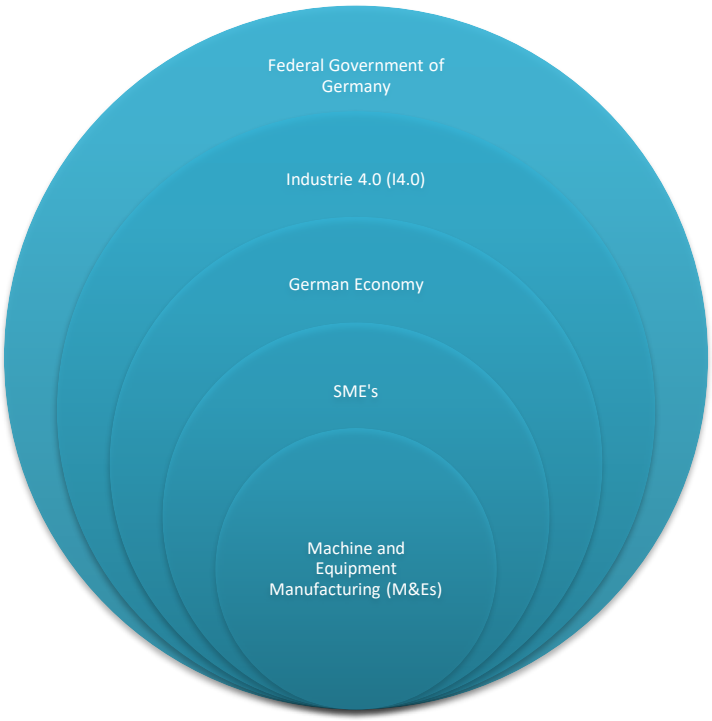

Figure 3 Relationship between focuses of research

1.4 Research Objectives and Goals

To determine how the Federal Republic of Germany can support German M&E SMEs, in I4.0 adoption, the thesis will examine three separate research questions. By collectively addressing all the research questions together, it will be possible to provide recommendations on how the federal government can adapt the future policy to support this sector in I4.0 transformation. The first and second research questions will be addressed individually, and once they have been investigated and addressed, will it be possible to address the third research question through the answers to the first two research questions. The three research questions are listed in order:

I. What are the guiding policies and aimed outcomes which the German government sought to have attained in German tool machine manufacturing?

II. To what level of maturity in the application and IT landscape has Industrie 4.0 been incorporated into the German machine tool industry in accordance with German state policy and aimed outcomes?

III. How can the emerged successes and challenges be incorporated in the development of German I4.0 policy surrounding future High-Tech strategy and adapted to achieve and reflect the desired progression of the state?

The first research question will be addressed through the conduction of interviews with experts in the field of I4.0, the federal government, and individuals from the private sector, which represent the M&Es SMEs sector. The interview questions will be drafted around previous research into federal government policy, which was attained during the literature review, and based upon guiding questions from the *System Integration Maturity Model Industry 4.0* (SIMMI 4.0) questionnaire to address the second research question.

The second research question will be addressed by utilising the SIMMI4.0 maturity index, which will be adopted to examine selected M&E SMEs in Germany to determine the level of I4.0 progression within the enterprise. Through conducting a maturity analysis, it will be possible to determine the level at which selected M&Es are at concerning I4.0 transformation, therefore, allowing the small sample size to serve an exploratory multiple-case study approach to determine an average level of progression.

The third research question of this thesis will incorporate the findings from the first and second research questions in order to conclude what selected M&E SMEs have achieved in regard to I4.0 adoption and where there are still challenges that need to be overcome in order for these enterprises to achieve the level which the federal government desires and for the continuous advancement of I4.0 adoption.

Through addressing the first two research questions, it will be possible to address the third research question through utilising the results and data obtained to support the discussion of providing policy recommendations. The research questions were designed so that each question being addressed will first require having the previous question resolved to support the research being conducted in the preceding research question.

2 Literature Review

This section will seek to analyse all previously known information pertaining to German federal policy and government expectations regarding I4.0 adoption within the manufacturing industry, and which will directly relate to the machine tool SME sector in Germany. The Literature Review section will be broken down into three main fields of literature review to support addressing all three research questions. The first section (2.1) will be a Policy Analysis of German federal policy surrounding I4.0 adoption in the manufacturing sector to understand what the government seeks for SMEs to have achieved. The policy analysis will provide a profound outline and base for further investigation into previous and present government expectations to support the construction of policy recommendations and a baseline to conduct an evaluation. Finally, this section will analyse the critical objectives for I4.0 adoption and transformation which the government seeks enterprises to have achieved to determine the enterprises' successes when comparing against the later maturity model results.

The second section of the literature review (2.2) will evaluate and analyse maturity models designed for investigating I4.0 adoption. This section will analyse the current maturity models available, which will support the conduction of a maturity evaluation for the research. The evaluation will occur based on the most predominantly utilised maturity models for I4.0 within Germany and will be analysed based upon predetermined criteria for selection to select the best fitting maturity model for enterprise evaluation.

The third section of the literature review section (2.3) will seek to examine pre-drafted literature surrounding challenges and successes in I4.0 adoption to determine what has been known as barriers and successes within the field. This section will support further investigation from the maturity index and interviews, which will be conducted with I4.0 experts, as it will indicate reoccurring themes in these sections while additionally indicate areas that have been addressed already. Through this analysis, it will be possible to determine further if the current federal policy reflects the status of the I4.0 transformation within Germany’s SME machine tool sector or if the policy needs to be adapted to accommodate the situation further.

2.1 From Technology to I4.0 an Analysis of German Federal I4.0 Policy

To address the three research questions, a background of German federal policy surrounding I4.0 needs to be provided and analysed to determine the outcomes that the government seeks to have attained through guiding policies. An in-depth analysis of the development of the I4.0 policy in Germany will advance understanding of how the current aimed outcomes came to be selected and why they aim to achieve a specific goal. The

policy analysis will be conducted by building upon the previous policy analysis conducted initially by (López-Gómez Leal-Ayala, Palladino, & O'Sullivan, 2017), and later expanded by (Horst & Santiago, 2018). Furthermore, this section will examine the previous policy indicated by Horst & Santiago (2018) to determine the previous objectives of attainment by the federal government and then provide additional analysis of the most current I4.0 policy; thus, allowing the ability to identify any reoccurring challenges and success that enterprises face and how current aimed objectives came to formulate policy.

2.1.1 High-Tech Strategie 2006

Federal policy surrounding I4.0 in Germany arose in 2006 within the publishing of the High-Tech Strategie by *Forschungsunion and the Expertenkommission Forschung und Innovation* (EFI, Expert Commission Research and Innovation) (Horst & Santiago, 2018). The policy was launched initially by the *Bundesministerium für Bildung und Forschung* (BMBF), which is the German Federal Ministry of Education and Research. The policy aimed at promoting competitive advantages through innovation rather than reduction of production cost, which had previously seen the transferal of manufacturing from Europe to Asia to drive down production costs. Innovation through cross-cutting technologies was the main focal point of this policy; although the document did not mention I4.0, the aim was primarily focused on manufacturing technologies, which are a component of what would later be regarded as I4.0 (Horst & Santiago, 2018; BMBF, 2006). The focus of manufacturing technology innovation was additionally mentioned within the adoption of nanotechnology in production, and promotion of SME innovation capacity, which became the future building blocks of I4.0 policy (BMBF, 2006).

2.1.2 Deutschland Digital 2010

Deutschland Digital was released in 2010, which was the initial holistic strategy for Germany's digital future. The *Bundesministerium für Wirtschaft und Energie (*BMWi) [Federal Ministry for Economic Affairs and Energy] introduced the policy to create a framework for government intervention to support the private sector in the adoption and integration of ICT enabled technologies. Deutschland Digital came about due to the increased influence of ICT technology in the German economy and aimed to secure a leading role as an ICT enabled nation (Horst & Santiago, 2018). The policy sought not exclusively to secure a leading position but to "strengthen growth, competitiveness and jobs through digitalization" (Horst & Santiago, 2018). The BMWi sought to integrate vertically and horizontally the ICT industry in Germany with traditional industries which

support the economy to construct an intelligent network and ensure the competitiveness of the German economy.

Deutschland Digital is regarded as the main foundation of I4.0 strategy in Germany, and although it was developed in November of 2010, the aimed outcomes and projects which it focuses on are still incorporated into the main ambitions of the government (Horst & Santiago, 2018). Deutschland Digital, when initially published, sought to promote the importance of cloud computing, data security and copyright protection in the private sector, and the further development of digital network creation and R&D on IoT and system integration (Horst & Santiago, 2018; BMWi, 2010). Additionally, the Deutschland Digital focused on providing support for open standards and interoperability, providing investment and development in ICT infrastructure within Germany, and promoting education and competencies to support a future work environment (BMWi, 2010).

The previously aforementioned aimed outcomes of Deutschland Digital are still a part of the main functions of the current digital strategy in Germany, and various programs are still conducted to fulfil these vital outcomes for the German economy. These fundamental building stones of German I4.0 policy are SME centric focused, intending to develop a foundation at the heart of the German economy by aligning traditional manufacturing with ICT-enabled technologies and competencies (Horst & Santiago, 2018; BMWi, 2010). The Deutschland Digital government policy for standardisation and framework for all ICT-related government interventions sought to identify future challenges in I4.0 adoption and began to transition the German private sector by addressing these back in 2010 to better support a smooth transition transformation in the future (BMWi, 2010). The government identified the main compositions of I4.0 and outlined the importance of building and developing competencies within these areas for SMEs to build upon, such as cloud computing and data privacy, which have become cornerstones of I4.0 development. Additionally, while identifying these areas, Deutschland Digital indicated areas in which the government must address to support and encourage German leadership in I4.0, which included vocational training to ensure a sufficient employment pool for the SMEs and provide ICT infrastructure on a macro level through telecommunication lines (BMWi, 2010).

2.1.3 High-Tech Strategy 2020

German High-Tech Strategy 2020 became the successor of German federal policy surrounding I4.0; although the document neglects to mention I4.0 by name, it mentions functions and the relationship between ICT and manufacturing (BMBF, 2010). High-Tech Strategy 2020, which was published in 2010 and updated in 2012, became a

government pledge for ICT strategy support and action programme which the working groups would later chair in order to address the furthering of cloud computing in the sphere of development, testing, security, and standards (BMBF, 2010). The policy document initially emphasised "smart objects", particularly robots for industry, while simultaneously expanding the development of a national roadmap for embedded systems and IoT. The pair of terms "smart object" and "IoT" were both for the first time mentioned in the German High-Tech Strategy 2020, which were identified as key performance indicators in further advancement of ICT adoption in SMEs (BMBF, 2010). These two terms would later be mentioned in relation to I4.0 in the 2012 Action Plan High-Tech Strategy 2020, as the focal point for SME adoption and integration where as I4.0 would be referred to as the business process (Horst & Santiago, 2018).

The German High-Tech Strategy 2020 also sought to create the current relationship regarding I4.0 policy drafting in Germany by forming working groups chaired by industry, researchers, and government ministries (BMBF, 2010). The creation of working groups was designed to promote the co-creation of I4.0 policy in Germany. The stakeholders invested in the transformation work in partnership to share data, promote transparency on the development and transition of digitalised manufacturing, and promote further cooperation between German industrial partners (Horst & Santiago, 2018). The creation of the working groups that became responsible for promoting future ICT projects and policies profoundly affected the progression of I4.0 in Germany as they became responsible for the future progression of I4.0 advancement within the country, and therefore, would determine the direction of policy (Horst & Santiago, 2018).

2.1.4 Action Plan High-Tech Strategy 2020

I4.0 previously had not been addressed in its entirety in German federal policy, but rather the previous policies focused on developing macro-level ICT capabilities and promoting innovation in SME's. In 2012, following the creation of the working groups by the federal government in the previously released High-Tech Strategy 2020, the term I4.0 finally became the centre focus of technology and manufacturing policy in Germany with the publishing of the Action Plan High-Tech Strategy 2020 (BMBF, 2012). The working groups outlined the importance of I4.0 in the creation of and adoption of ICT supported manufacturing. Incorporating smart objects and IoT in the previous 2020 HTS indicated a need to support an overall approach to adoption, and I4.0 became the means of such. The Action Plan High-Tech Strategy 2020 made I4.0 one of the ten strategic initiatives of the action plan for implementation (BMBF, 2012). The newly outlined strategic initiative of I4.0 built upon the previously outlined policies in ICT, manufacturing, and innovative SMEs to integrate the previous policies. Under the 2020

action plan for I4.0, technology, economic, and social policy was developed surrounding I4.0 adoption, incorporated additional previously implemented programs from Deutschland Digital, and made those programs more I4.0 centric focused accumulate additional extra government-supported funding and resource support.

Action Plan High-Tech Strategy 2020 assumed further support from the BMBF, which sought to adopt a research agenda that concentrated on smart factories, embedded systems, IoT, and *virtual reality* (VR) (BMBF, 2012; Horst & Santiago, 2018). Through combining research capabilities with working groups consisting of academics, professionals and government representatives, the possibility of research to be conducted in partnership with different stakeholders within I4.0 while maintaining an SME focused approach became possible. Thus, the creation of the working council on I4.0 was created in order to coordinate the actions and recommendations pertaining to I4.0 transformation (BMBF, 2012). This working group would later transition into *Plattform Industrie 4.0*.

The working group published a two-tiered strategy in 2012 for I4.0 implementation, which is still incorporated in the German federal strategy and is utilised to predetermine which approach the company implementing I4.0 seeks to achieve or attain in relation to federal government expectations (BMBF, 2012). The two-tiered strategy is divided into two aspects, the first being attaining a leading supplier role of I4.0 technology and research and the second becoming a leading market for I4.0 development and implementation (BMBF, 2012). The two-tiered strategy categorisation aims at ensuring federal government ambitions are achieved. The aforementioned first strategy of attaining a leading supplier role of I4.0 is focused on the aspect of strengthening German industries supplying capabilities in relation to I4.0 technology, and securing investment for innovation research, thus, supporting the aim of enforcing intellectual property rights and protecting German innovation from a legal perspective (BMBF, 2012). The second approach of becoming the leading market for I4.0 was centred around distributing I4.0 technology throughout the entirety of the German production chains, predominantly in *Multi-National Corporations* (MNCs) and SMEs (BMBF, 2012). The holistic and vertical integration of I4.0 throughout the entirety of the German economy will support the federal government's aims in becoming the leading market for I4.0. Within the second strategy, the objective can only be obtained through transferring knowledge and technology across sectors and companies within the German economy; however, this can only be supported with secure digital infrastructure, which is the responsibility of the federal government to develop.

Following publishing the two-tiered strategy for the federal government by the working group created to tackle I4.0 implementation in Germany, the German ministries

developed Plattform Industrie 4.0, which became the successor to the working group and will hence forth be referred to as such. Plattform Industrie 4.0 (n.d.) became an organisation comprised of various working groups, think tanks, academics, ministries, unions, and enterprises involved in I4.0. Plattform Industrie 4.0 (n.d.) is the organisation that is currently responsible for any further development of I4.0 in Germany; although it does not possess power in policy implementation, it does, however, work on behalf of the federal government in research and development surrounding I4.0. The organisation is tasked with providing policy suggestions to ministries and companies within Germany to support their transformation process in I4.0 adoption.

I4.0 federal policy in Germany is a combination of various policy documents created by different ministries, organisations and working groups. Although many documents prior to the coining of the term Industrie 4.0 in 2011 did not mention the term by name, they did, however, mention attributes of the definition of Industrie 4.0, which would later be adopted within the federal approach for strategy implementation. The prior documents published, which were listed within this section of the thesis, contribute to the overall development of I4.0 policy. Portions of these documents provided the foundation for what would become Germany's I4.0 approach to adoption and implementation (Horst & Santiago, 2018). Although some documents focus on aspects of I4.0 such as AI and ICT exclusively, these documents provided the foundation for the overall government approach to I4.0 adoption as these topics independently provide policy adoption support for the topic being discussed (Horst & Santiago, 2018). However, I4.0 is an umbrella term that includes a wide variety of different individual topics, that once brought together, would work interchangeable and integrated vertically and holistically. Once the term I4.0 became adopted in German policy as a topic that ought to be discussed, the development of the I4.0 strategy included and modified the previous topics to incorporate them into I4.0 through including a more comprehensive digital manufacturing approach.

2.1.5 RAMI 4.0

The Reference Architecture Model Industry 4.0 (RAMI4.0) was developed in partnership by the working group Plattform I4.0, VDI, and ZVEI in 2016. RAMI4.0 is currently the overall encompassing document published by the working group, which has had profound effects on the discussion of I4.0 within Germany and abroad (Singapore Economic Development Board, 2017; Plattform Industrie 4.0, 2018; BMWi & Plattform Industrie 4.0, 2018). RAMI4.0 is a service-oriented architecture that was developed to establish a common understanding of the standards, norms, and practices in the deployment of I4.0 operations and discussion (VDI & ZVEI, 2015). Furthermore, the

model is designed to provide further guidance in I4.0 by administrating its three-dimensional map, which indicates the most pressing aspects of I4.0.

RAMI 4.0 focuses on supporting the product life cycle assessment, which is the first dimension and is through four key areas: development, maintenance usage, production, and maintenance usage (BMWi & Plattform Industrie 4.0, 2018). These areas allow for the assessment of the product from the initial development stage during manufacturing to operator/ end customer, thus identifying the specific areas in which I4.0 contribute within the entirety of the process, including maintenance along the way for machines and products (BMWi & Plattform Industrie 4.0, 2018). Additionally, it allows for the ability to indicate when different parts of a non-linear process are required to communicate with one another.

The second dimension of RAMI4.0 is the Business architecture which supports the enterprise depending on which focuses it seeks to analyse. This section is further divided into six-layered sections: Business, Functions, Information, Communication, Integration, and Asset (BMWi & Plattform Industrie 4.0, 2018). These assessment functions of the architecture have a two-tier fold which assesses both the operations in the "Digital World/Virtual World" and the "Real" world, thus providing a clear indication of how both words interact with one another. (BMWi & Plattform Industrie 4.0, 2018)

The final and third dimension is the factory hierarchy or Hierarchy levels which refers to the new world of I4.0 and the emphasis on a "connected world", "Flexible Factory", and "Products" (BMWi & Plattform Industrie 4.0, 2018). In order for a focus on I4.0 to be met, it must be made possible that "participants interact across hieratical levels" and that "all participants are able to communicate with each other" (Plattform Industrie 4.0, 2018). The third dimension must allow for limited barriers and flexible systems with the possibility for all objects and actors to communicate and are a part of the entire network (Plattform Industrie 4.0, 2018).

The development of RAM4.0 has allowed for the discussion of I4.0 to progress further with the codified standardisation of aspects of what I4.0 is. Since the release of RAMI4.0, Plattform I4.0 has collaborated with global partners and has supported the development of I4.0 standards in foreign nations (Plattform Industrie 4.0, 2018). The current aim of the organisation is to develop a global standard in which RAMI 4.0 will be the foundation. Since the release of this architecture, it has been possible to identify its contents in policy, to enhance I4.0 adoption in enterprises. The possibility of companies being able to identify specific characteristics and portions of their operations, supported the importance of integrating the standards into the *Digital Strategy 2025* policy (BMWi, 2016b).

2.1.6 Digital Strategy 2025

The *Digital Strategy 2025* is the current digital strategy which is overseeing the aims of the federal government regarding digital technology and support competencies. The policy is not specific to I4.0, but instead adopted a focus on digital technologies across all sectors and domains of society to provide a step-by-step approach to what needs to be achieved to support further digitalisation. The Digital strategy 2025 adopted ten categories of importance, which is believed to support digitalisation in Germany. The "10 Steps Toward the Future" published by the BMWi (2016b) are:

1. Creating a gigabit optical fibre network for Germany by 2025.
2. Launching the New-Start-up-Era: Assisting start-ups and encouraging cooperation between young companies and established companies.
3. Creating a regulatory framework for more investment and innovation.
4. Encouraging "smart networks" in key commercial infrastructure areas of our economy.
5. Strengthening data security and developing informational autonomy.
6. Enabling new business models for SMEs, the skilled craft sector and services.
7. Utilising Industry 4.0 to modernise Germany as a production location.
8. Creating excellence in digital technology research, development and innovation.
9. Introducing digital education to all phases of life.
10. Creating a Digital Agency as a modern centre of excellence

The *Digital Strategy 2025* is not specifically directed at I4.0, besides for the *step toward the future* number seven which directly focus on promoting I4.0 to modernise Germany and its production capabilities. The other nine steps of the policy focus on addressing other capabilities that will enhance the digitalisation efforts in Germany (BMWi, 2016b). Although these policies do not focus directly on I4.0, the successful implementation of them will have both direct and indirect effects on I4.0 practices, as in order to implement I4.0 fully into an enterprise, there must be interoperable operations and solutions across sectors. The Digital Strategy 2025 indicates the importance of interoperability within its document, as German companies must be interoperable in both national and international markets to hamper the benefits of I4.0; otherwise, significant

benefits will not be able to be achieved, and thus, an extended emphasis on I4.0 research and partnership development is promoted (BMWi, 2016b).

The step towards the future number seven is broken down into five main points which can be categorised as SME assistance, Funding and Research, I4.0 Issues Recommendations, Action plan for Standardisation, and Interoperability (BMWi, 2016b). These categories are not stated within the policy document, but rather for simplicity, they were created based on the theme of the policy point objective.

SME assistance is an overlying theme within the policy document due to SMEs making up a large portion of the German economy and the importance of digitalisation of this sector. Therefore, the policy sets to develop assistance programs that will "provide information and finance investment" along with increasing awareness of I4.0 within SMEs and society (BMWi, 2016b). The policy identified that finances and information are a challenge for SMEs due to the size and abilities of the organisations; therefore, the support mechanisms are intended to adapt the business models of the SMEs to prepare for I4.0 (BMWi, 2016b). Additionally, awareness of I4.0 presents a challenge for I4.0 transformation due to employees not being aware of how it impacts their operations and for companies to commence upon the integration process of the supply chain; thus, the financial investment seeks further to increase awareness on the topic (BMWi, 2016b).

Funding and research were additionally a theme within the policy, which sought to provide greater financial support in development programs of ICT "sensor and actuator technology found in machines and robots" (BMWi, 2016b). The policy seeks to provide larger financial support for enterprises that enhance Germany's digital independence by supporting operations that are crucial to the implementation and integration of I4.0 operations (BMWi, 2016b). The funding is not exclusive to enterprises but, additionally, for research and innovation projects in microelectronics. The financial support from the policy indicates that Germany has adopted a focus that seeks to ensure manufacturing and ICT security so far that its I4.0 operations do not fault due to the supply chain and resources required for transformation.

I4.0 issue recommendations was a theme that was emphasised within the policy surrounding challenges that I4.0 faced across the manufacturing sector. The issues indicated in the policy were those that were raised by the working groups of Plattform I4.0 and were in the categorical areas of "standardisation, legal framework, IT security and work" (BMWi, 2016b). These categorical area issues would later translate over to the *2030 Vision for I4.0* policy to support and resolve the issues being faced, thus being adopted as the aims that the federal government seeks to achieve.

An action plan for standardisation was an additional theme raised in the policy and continuously raised in previous policy publications. The challenge of standardisation of I4.0 transformation and practices has been a reoccurring theme in numerous federal policies since the coining of the term I4.0. The action plan that the policy seeks to achieve incorporates an international focus of standardisation through the inclusion of RAMI 4.0 (BMWi, 2016b). The policy objective of this theme is to continue to maintain Germany's leadership position in I4.0 transformation and developments, in which the German industry will promote RAMI 4.0 as the leading standards and norms for I4.0 discussion. International adoption and incorporation of RAMI 4.0 will serve to ensure Germany's leading supplier and user role of I4.0 globally through endorsing German digitalisation capabilities (BMWi, 2016b).

Interoperability is the final theme of the 2025 Digital strategy surround I4.0, which seeks to "strengthen cooperation on an international level" and promote "bilateral cooperation with important partner countries" (BMWi, 2016b). Interoperability, when implemented nationally, will enable German enterprises to conduct efficient operations to the fullest extent of I4.0 capabilities if fully implemented throughout the business value chain of the country (BMWi, 2016b). However, greater cooperation on an international level and bilateral cooperation with partner countries will serve to provide accessibility to foreign markets for German SMEs. Integrating and working bilaterally on I4.0 advancement will reduce operation barriers and enhance the ability to conduct business internationally, thus, continuing to achieve the mandate of ensuring that Germany is a leading supplier and user of I4.0 (BMWi, 2016b).

The I4.0 focus of Digital Strategy 2025 is to promote digital transformation both on the national and international levels to achieve a leading supplier and user role of I4.0 for Germany (BMWi, 2016b). The topics and themes presented within this policy have been adopted into the 2030 Vision for Industrie 4.0 to ensure that that aims will be achieved by 2025 and additional objectives by 2030. The policy makes mention of Big Data and I4.0 throughout its briefing as two septate discussion points for greater policy focus; however, both topics of discussion can serve to support one another in operation (BMWi, 2016b).

2.1.7 2030 Vision for Industrie 4.0

The *2030 Vision for Industrie 4.0 Shaping Digital Ecosystems Globally* is the current federal policy surrounding I4.0 development and adoption within Germany. The policy document was published by Plattform Industrie 4.0 and in joint cooperation with the Federal Ministry for Economic Affairs and Energy and the Federal Ministry of Education and Research (Plattform Industrie 4.0, 2019b). The 2030 Vision for Industrie 4.0 adopts

a different approach to the previously published policies so far that it presumes that I4.0 adoption has already begun in most enterprises within Germany. The 2030 approach aims to support already commenced I4.0 practices to achieve its three main fields of action: autonomy, interoperability, and sustainability (Plattform Industrie 4.0, 2019b). Figure 4 illustrates the three main fields of action for the 2030 Vision for I4.0, representing how the three fields are entwined to achieve the policy's overall objectives.

The *2030 Vision for Industrie 4.0* will be considered as the main policy for I4.0 adoption and transformation throughout this paper. Although the *2025 Digital Strategy* contains a section of I4.0 transformation strategy, the main themes from that policy were later adopted into the 2030 vision, which is more specific to the topic. Therefore, due to the I40 focus of the 2030 vision and the lack of focus within the 2025 digital strategy, the former will be adopted and regarded as the current policy on the matter of I4.0 transformation in Germany.

2.1.7.1 Interoperability

The 2030 vision for I4.0 additionally adopts a different perspective than the previously published policies and builds upon the previous two-tiered strategy from 2012, which aims to secure a leading supplier and that of a leading market role in I4.0 for Germany. The inclusion of interoperability into the outlined strategic action of the 2030 vision is a continuation of the two-tiered strategy from 2012 (Plattform Industrie 4.0, 2019a). The inclusion of Interoperability supports the previous two tired strategies of 2012 in so far that it allows for German technology, manufacturing, and leading position in I4.0 advancement to be enhanced through the aligning of practices not exclusively within Germany but additionally in Europe and globally.

Previous German I4.0 policy was developed around the focus of incorporating ICT into manufacturing within Germany; however, the 2030 approach adopted a broader perspective than that of previously published policy. The current policy focuses on not solely Germany but additionally focused on a European and international perspective of I4.0 and where German leadership would be in that perspective. The emphasis on the importance of openness and willingness to collaborate with European and international partners became a focal point within the newly published policy (Plattform Industrie 4.0, 2019a). As for the previous strategy to be achieved, it is crucial to support the objective of cooperation and support with a diversity of partners outside of Germany for a holistic approach to be incorporated.

The first contribution section of the policy to the main field of action, interoperability, is that of *standards and integration*. Standards have been at the forefront of ICT and I4.0

policy actions in previously published documents, as there needed to be a concrete understanding of I4.0 implementation to allow for future integration and communication. The need for common stands that would determine the common communication structures, languages, vocabulary, semantics, and rules for cyber security and data protection became a main focus that needed to be addressed in previous policy to develop the standardisation of I4.0 (Plattform Industrie 4.0, 2019a; Horst & Santiago, 2018). *The Reference Architectural Model Industrie 4.0* (RAMI4.0) was published by the *German Electrical and Electronic Manufactures Association* (ZVEI) and its partners, which is regarded as the current standard for I4.0 within Germany (Plattform Industrie 4.0, 2019a; BMWi, 2018). RAMI4.0 provided the beginning of standardisation of I4.0 within Germany. However, to achieve interoperability with other partners within Europe and globally, the further need to integrate and develop global standards for I4.0 is outlined within the 2030 vision, and Germany must see this through as it is currently the global leader in developing I4.0 standards (Plattform Industrie 4.0, 2019a).

The second section of the field of action, Interoperability, is that of ensuring the development of a *Regulatory Framework*. The Regulatory framework section indicates the importance of developing one at the national, European, and international level "in order to ensure networking, exchange and cooperation in open ecosystems with fair and equal conditions for all stakeholders" (Plattform Industrie 4.0, 2019a). I4.0 requires governance rules to ensure that standards are met and that the main focus of data privacy is upheld due to the concern of the use of large quantities of data.

The final portion of the 2030 vision on the main field of action, Interoperability, is that of *Decentralised Systems and Artificial Intelligence*. This section outlined the importance of a decentralised, autonomous system in manufacturing, particularly in the B2B sector (Plattform Industrie 4.0, 2019a). The policy stated, "decentralised, autonomous systems with embedded intelligence are of far greater significance in the digital ecosystems of industrial value creation (B2B)" (Plattform Industrie 4.0, 2019a). This policy statement is the first time German policy has indicated that AI produces a far greater value for B2B than that of B2C, indicating that AI policy moving forward will continue to have a greater emphasis on that of the industrial sector (Plattform Industrie 4.0, 2019a). German policy surrounding AI in I4.0 is designed to further the "cooperative and transparent use and interconnection of various types of machine and user data" as this would allow for the development of new solutions and business models in further advancement in industrial practices (Plattform Industrie 4.0, 2019a). Therefore, the policy surrounding AI in I4.0 is emphasised on greater integration into the value and business chain to further I4.0 advancement and provide solutions to current challenges in ICT enabled manufacturing

with the belief that AI produces beneficial use in industrial practices which can only be attained alongside big data and applied smart data (Plattform Industrie 4.0, 2019a).

2.1.7.2 Autonomy

The 2030 Vision for I4.0 adopted a focus on Germany's role in promoting interoperability of stakeholders within Europe and internationally; one of the other focuses for the vision is autonomy, which adopts a more domestic-focused approach. The focus of incorporating autonomy within I4.0 adoption is to ensure that the perspective that the "self-determination and free scope for action guarantees competitiveness in digital business models" can be maintained (Plattform Industrie 4.0, 2019a). Within the 2030 Vision, autonomy comprises three requirements for the I4.0 ecosystem: *Digital Infrastructure, Safety and Security, and Technology Development* (Plattform Industrie 4.0, 2019a).

Digital infrastructure is a reoccurring topic within German policy on I4.0 as this is the backbone for providing German enterprises with the means to compete domestically and internationally. Within the 2030 vision, digital infrastructure is addressed as a concern that needs to be resolved by upholding the ability to provide German enterprises with equal accessibility for all without restrictions to promote competition (Plattform Industrie 4.0, 2019a). Additionally, when linking the main fields of action of autonomy and interoperability, resilient digital infrastructure is crucial in ensuring the ability to exchange, collect, and analyse data that is exchanged in cross-border and cross-sectoral interoperable activities (Plattform Industrie 4.0, 2019a).

Safety and security have been a fundamental principle of I4.0 adoption in previous policy publications. Data protection and privacy enable manufacturers to incorporate ICT technology within their operation, which must be protected from malware and corporate espionage domestically and abroad. The 2030 Vision included safety and security as the main focus of autonomy. To ensure a high level of global confidence in I4.0 adoption, it is necessary to ensure that the data that is exchanged holistically and vertically is protected for all stakeholders involved (Plattform Industrie 4.0, 2019a). With the continuous advancement toward transparency and anonymization of data, it has become ever more crucial to ensure that safety and security are incorporated in I4.0 transformation to continue that the risks are minimalized, particularly when there is data being exchanged in cross-border activities, as I4.0 relies heavily upon access to large data pools from operations to customer product usage (Plattform Industrie 4.0, 2019a).

Technology development is the final principle that makes up the main field of action, autonomy and addresses research and development requirements in the core areas of

industrial value creation (Plattform Industrie 4.0, 2019a). The promotion of continuous technology development is encouraged; however, a focus on data security and protection has become the main focus of new technological advancement, as, without an initial consideration of this aspect, it is possible that it will be detrimental to the other main fields of action which are interoperability and sustainability (Plattform Industrie 4.0, 2019a). The 2030 vision was constructed on a triangular based field of actions in which the actions from one field will have direct implications on the others; therefore, it is crucial to ensure that particular instances are considered (Plattform Industrie 4.0, 2019a). Finally, the technology and development principle moreover requires a focus upon the development of technologies that adopt a dynamic integration approach. A dynamic integration approach differs from that of a static integration which has preloaded content within the technology on a schedule, whereas the dynamic integration allows for the real-time exchange of information to the end-user upon request from the source system (Plattform Industrie 4.0, 2019a). Dynamic integration is a crucial component for I4.0, and it is required for the next step of I4.0 transformation within the transmission of data and can only be achieved with proper digital infrastructure (Plattform Industrie 4.0, 2019a).

2.1.7.3 Sustainability

The field of action Sustainability within the 2030 Vision focuses on integrating sustainability in I4.0 practises through two directions. The first direction focuses on embedding sustainability within I4.0, which is accomplished through utilising sustainable technology and practices within the manufacturing process (Plattform Industrie 4.0, 2019a). The second direction focuses on ensuring that I4.0 "permits substantial progress on sustainability" (Plattform Industrie 4.0, 2019a). Although previous policy which is related to I4.0, focused on sustainability in the sense that high-quality products are utilised to reduce waste, this portion of the second direction differs from other policies as it attempts to address and include the societal impact of I4.0 within Germany to safeguard employment and high labour.

Decent work and education are fundamental points outlined under sustainability in the 2030 vision. Although education was a focal point in previous governmental policy to ensure that a skilled labour force is available to SMEs to implement I4.0, the education focus in the 2030 vision is expanded (Plattform Industrie 4.0, 2019a). The focal point of education was expanded in the 2030 vision to include the proactive response to ongoing skill shifts, in which life-long learning will be required to maintain competitiveness (Plattform Industrie 4.0, 2019a). Within the educational focuses, an emphasis is placed upon continuous learning as there is an expectation that I4.0 will rapidly and continuously disrupt markets (Plattform Industrie 4.0, 2019a). Therefore, it is crucial that training is

offered to employees to ensure that employees are continuously up to date on the skills within their field. Within the decent work focus of this policy section, an advancement on working conditions through placing humans at the centre of I4.0 can innovate and create a competitive user industry (Plattform Industrie 4.0, 2019a). Therefore, the participation from all stakeholders within the process can continue to support I4.0 advancement and can only be accomplished by supporting the company's employee and shop-floor level base.

Social Participation in the sustainability field of action is referred to as the value of I4.0 as providing "a process of transformation which embraces the whole of society, entailing far-reaching changes for the stakeholders" (Plattform Industrie 4.0, 2019a). The goal of I4.0 within this section is regarded as attempting to achieve "that the industrial and social innovations generated by Industrie 4.0 should not only create challenges for these stakeholders but also and in particular new opportunities." (Plattform Industrie 4.0, 2019a). The policy outlines the importance of dialogue between stakeholders and across sectors, companies, and societies to address the issues with embracing the uses of digital technologies and AI in daily lives. The promotion of dialogue across all domains is designed to enhance the advancement of I4.0 by addressing the challenges currently in play.

The final component of sustainability within the 2030 Vision is mitigating climate change. This portion of the policy acknowledges the potential of I4.0 and how ICT-enabled technology can support resource efficiency, which can support and act as a means to address other climate change projections which the government seeks to attain (Plattform Industrie 4.0, 2019a). Greater emphasis on closed material cycles through an entire product life cycle can be achieved through the adoption of a combination of a design-based and process-based approach. A design-based approach is referred to as a co-creation relationship between research innovators and practitioners in which, through working closely, it is possible to design products that collect data on their efficiencies and effectiveness through iterative analysis (Plattform Industrie 4.0, 2019a). A process-based approach is an approach where the enterprise views and manages operations as one entire process rather than individual singular processes, allowing the company to follow through the product's life-cycle (Plattform Industrie 4.0, 2019a). Through the transformation of the product creation approaches, the policy aims to enhance the I4.0 role in acting as "a key enabler for the circular economy, and for environmental protection and climate action in general" (Plattform Industrie 4.0, 2019a).

The 2030 Vision for Industrie 4.0 is the most current policy directive for I4.0 adoption in Germany at the time of publishing this thesis. The 2030 Vision is a combination and

build-up of previously published policy documents on manufacturing, ICT, and recently developed I4.0 policy. The most current policy contains policy suggestions on which enterprises and researchers should focus on regarding I4.0 adoption in Germany (Plattform Industrie 4.0, 2019a). However, it further differs from the previous policy regarding a more human-centric approach, a wider focal group of stakeholders, and greater emphasis on integrating currently implemented I4.0 standards rather than a starting point of implementation which is what the previous policy entailed (Plattform Industrie 4.0, 2019a). It was possible for the current policy to adopt a more integrating policy perspective due to publishing common standards approach within Germany, which has allowed for the ability to identify the common positions, challenges, and terms within the field.

Figure 4 provides the outline of how the main fields of action that are a part of the 2030 Vision for Industrie 4.0 are related and support one another to shape the digital ecosystem in Germany and globally. Additionally, the figure indicates what components are part of each main field of action, demonstrating what constitutes the main objectives of the policy.

Figure 4 2030 vision for industrie 4.0 policy Plattform Industrie 4.0 (2019b)

2.2 Maturity Model Selection

The research will focus on investigating how far German SMEs in the machine tool industry has achieved in relation to I4.0 adoption. One means to investigate and determine a specific means of adoption and transformation is through the utilisation of a maturity model (Bertolini Esposito, Neroni, & Romagnoli, 2019). Maturity models enable the

possibility of examining the transformation of a specific topic by evaluating the transformation in different levels of adoption. A maturity model “defines a basis for assessing and benchmarking and organisation, and in addition, it provides a basis for ‘strategic planning’ of investment to ensure continuous improvement and to move towards corporate objectives” (Bertolini et al., 2019).

The levels of adoptions or maturity levels are commonly divided into levels that represent stages within the transformation process, based upon the principles of the assessment (Pöppelbuß & Röglinger, 2011). These levels of maturity are determined by an evaluation based on questionnaires. Pre-determined questionnaires allow for a structured and standardize approach, which allows for consistency, thus allowing for the same results to be determined through replication and can be compared between different samples (Brennen, 2013). Therefore, the incorporation of a maturity index into this research will enable a standardized possibility to compare the I4.0 transformation in German machine tool enterprises and determine the enterprises readiness.

The incorporation of a maturity index into the framework will serve to aid in addressing all three research questions of this paper due to the unique ability to utilise the levels of the selected maturity index to create a standardised understanding of the expectations of which the German government seeks to have attained in German SMEs thus far. Additionally, it will allow the ability to determine the level of maturity achieved in the selected enterprise for this research. The integration of a maturity index will enable the ability to cross-examine both government expectations and what has been achieved in the Mittelstand by utilising the same maturity index to create a standardized understanding. Thus, the adoption of a maturity index in this paper will hence allow for the possibility of providing a standardized level of evaluation of the adoption, enabling the ability to determine the level which seeks to be attained by the government and the actual level of attainment which has been achieved in German machine tool SMEs.

Fundamental research utilising maturity models in the field of I4.0 transformation has been scarcely undertaken by researchers to evaluate the adoption and transformation process in relation to government policy. Current research consists of policy analyses of German and foreign policy, and investigations into the current challenges in transformation process as a broad scope (Horst & Santiago, 2018; Maisiri, van Dyk, Coeztee, 2021; Müller, Kiel, & Voigt, 2018; Müller, 2019). As for research regarding I4.0 maturity models, current research pertains to designing a wide variety of models which simultaneously include manufacturing, business, and ICT focus due to the expansive nature of I4.0 (Weber, Königsberger, Kassner, Mitschang, 2017; Dikhanbayeva, Shaikholla, Suleiman, & Turkyilmaz, 2020; Menon, Kärkkäinen, & Allan

Lasrado, 2016; Klötzer and Pflaum 2017; and Schuh, Anderl, Dumitrescu, Krüger, & ten Hompel, 2020a). The development of a maturity model that can be utilised to evaluate stages within I4.0 adoption has not yet been developed, as there had not been a standardisation or framework adopted regarding I4.0 until 2015 with RAMI 4.0 (VDI & ZVEI, 2015). Further research has been conducted surrounding evaluating theoretical maturity models within the field of I4.0 and determining what models are useful for practitioners (Dikhanbayeva, et al., 2020). Despite evaluation research of I4.0 maturity models, there has not been a model which directly compares transformation results against policy objectives within I4.0 to determine the success of the transformation. The lack of such a model provides challenges within the adoption process; as mentioned prior, I4.0 was planned by politicians and industrialists which sought to control the direction of the industrial revolution; therefore, the inability to measure its progress against the planned progression direction limits the possibility to continue to control and guide the transformation direction.

The adoption of the maturity index into the research paper's framework will be utilised in two separate ways. The first will be to utilise the framework to address the first research question by not incorporating the evaluation method of the maturity index but rather utilising the levels of maturity as levels of which the government seeks to have obtained. Through conducting interviews with researchers, government employees, and performing literature reviews, it will be possible to determine at which level in the maturity index that Germany's federal government seeks German machine tool enterprises to have obtained.

The second way the maturity index will be utilised will be to incorporate the maturity index as it is instructed to perform a maturity evaluation, which will be done on German machine tool enterprises participating in the research as case studies. Through the second means, the maturity index selected will be utilised in its entirety to provide a level of maturity that can then be compared against the level determined by experts. Instead of including a maturity level that the enterprise strives to achieve, the research will instead substitute this level for the level that experts indicated that the federal government seeks to achieve.

Maturity models design is regarded as possessing frameworks which "are often too specific to the application and the subject to be measured" (Bertolini et al., 2019). When selecting a maturity model to reflect the framework utilised within this research paper, there will be a set of requirements that it will need to fulfil for it to be selected. As the research being conducted is specific to the industry, company size, country, and I4.0, a generic model of an I4.0 maturity model would not be sufficient to support the

overarching research objectives outlined in this paper. The criteria to determine which maturity model best suits the research is indicated in Table 1.

Criteria Number	Maturity Model Selection Criteria
I.	Accessibility to maturity evaluation-based questions and formulas
II.	A focus on manufacturing and I4.0
III.	An application landscape centric focus on IT capabilities
IV.	Focus on SMEs

Table 1 Selection criteria for a maturity model

The first criteria was chosen as a measure of selection for a framework due to the ability to access the questionnaire surveys and formulas. There are different types of maturity models available that are developed by academics and private enterprises. The maturity models developed by the private sector do not provide access to the formulas and surveys, making it not possible to replicate the results further without paying for a third-party service to conduct the maturity evaluation as it is part of their business model.

The second criteria for selection were that the maturity model must have a focus on manufacturing and I4.0 as this was the main focus of the research paper. Therefore, a maturity index without a focus on I4.0 and manufacturing would not serve any value to the paper as it would not address the key concerns of the research. Although there are maturity models that aid in dissection and evaluation of the manufacturing process of an enterprise, there are current manufacturing processes that might not consider I4.0 adoption within particular sections of the industry as it does not provide particular value to its operations.

An application landscape centric focus on IT capabilities was additionally a requirement for the maturity index as although there are many different maturity models, many of which focus on different aspects of I4.0 such as organisation or business processes. To focus the research, the selection of the application landscape and IT capabilities within I4.0 were selected, and maturity models which consider other aspects within I4.0 would provide too large of a scope and provide extra data which would not be valuable to this paper and its research. As this research seeks to examine the centre of I4.0 within the German economy, to isolate individual areas to examine adoption, it is crucial to consider the application landscape specifically and IT capabilities of the

selected enterprise for evaluation exclusively, and the maturity model must reflect this desire for research.

The final requirement for the selection of the maturity index was to provide a framework that would focus on SMEs. As the focus of the paper is on SMEs, it is important to select a maturity model that will emphasise the size of the organisation being investigated. There are maturity models which consider exclusively large-sized digital transformations and those which focus on supporting SMEs; additionally, there are models that support all possible sizes of an enterprise.

2.2.1 In-depth evaluation of Maturity Models

This section will address the maturity index evaluation in greater detail to provide the reasoning on why each maturity index was under consideration based upon the pre-defined criteria and the basis for the final selection of a maturity index for this research. Additionally, it will provide greater detail on why or why not the maturity index was or was not selected based upon the predefined criteria. To determine which maturity index or model would best support the research being conducted, the maturity models were compared across all four selection criteria indicated in Table 1.

The criteria for maturity model selection were utilised to cross-compare all the maturity models under evaluation. In Table 2, each maturity model is represented and compared across the criteria for selection; if the model fulfils the criteria, a full black circle is indicated within the table to indicate its relevance within the specific criteria. This table provides a simplified overview of each maturity model under evaluation and how each model compares to each other for selection.

2.2.1.1 Assessment of Acatech Industrie 4.0 Maturity Index

The Acatech Industrie 4.0 Maturity Index is a maturity index that evaluates an enterprises transformation in I4.0 activities. This maturity index was developed by Acatech, which is the *Deutsche Akademie der Technikwissenschaften* (German Academy of Science and Engineering). Thus, the incorporation of this maturity index would provide legitimacy to this research's conduction due to the nature of the partnership of the development of I4.0 policy between Acatech, working groups, and the federal government, and a focus on supporting policy makers (Schuh, Anderl, Dumitrescu, Krüger, & ten Hompel, 2020a). Acatech’s maturity index evaluates the enterprises' implementation of I4.0 within four structural areas: resources, information systems, organizational structure, and culture, and the evaluation is based on a scale of 1-6, with six being the highest achievable level of I4.0 transformation (Schuh, et.al., 2020a). These

considerations would be evaluated across the functional areas of development, production, logistics, services, and marketing.

However, the Acatech maturity Index does not entirely support the scope of the research as its focus is on the entity of the organization or enterprise being evaluated and, therefore, considered additional variables within the I4.0 transformation period. Additionally, it was not possible to gain access to the working questions for the questionnaire to evaluate the maturity level due to the maturity index being a part of the operations at Acatech. Therefore, the adoption of the Acatech I4.0 Maturity Index for this research's maturity index was not selected; due to accessibility and the wider focus of the maturity index, which did not exclusively focus upon the IT and Application landscape.

2.2.1.2 Assessment of Digitalization Maturity Model for the Manufacturing Industry

The Digitalization Maturity Model for the Manufacturing Industry was considered for selection due to its focus on SMEs within the manufacturing sector that are implementing I4.0. This model developed by Klötzer and Pflaum (2017) provides an extremely detailed description of the nine dimensions and the maturity levels. Additionally, it provides interview questions suggestions for later evaluation. However, the challenges for adopting this model arose due to the lack of information on how to perform the evaluation and a lack of questionnaires. The inability to gain access to the evaluation methods along with a predominant focus on the supply chain of the enterprise being evaluated in comparison to an IT and application landscape focus prevented the selection of this maturity model for this research.

2.2.1.3 Assessment of Maturity Model for Industrial Internet

The maturity model for industrial internet was another maturity model initially considered for adoption within this research due to its unique focus on IoT technologies within manufacturing enterprises. This model presented the potential for adoption; however, the focus on the IoT technologies was too dominant and neglected the IT and application relationship (Menon, Kärkkäinen, & Allan Lasrado, 2016). Along with the lack of IT and application landscape focus, this model additionally "lacks information regarding defined dimensions as well as assessment tools and methods" (Dikhanbayeva et.al, 2020). With the inability to perform and replicate the maturity assessment, and the predominant focus on IoT technologies, this model was not selected for use.

2.2.1.4 Assessment of Maturity Model for Data-Driven Manufacturing (M2DDM)

The maturity model for data-driven manufacturing (M2DDM) was a maturity model which was considered to be adopted as the primary model for this research paper. M2DDM was considered due to its emphasis on the analysis of the IT architecture of the manufacturing sector of the enterprise being evaluated. Furthermore, as the focal point of this research is to evaluate the IT and application landscape of I4.0, this model presented possible best-fitting attributes for adoption. M2DDM additionally offers the ability to evaluate the enterprise from level 0, which is no integration performed, to level 5, which "describes the self-optimizing factory, which fully integrates all systems, devices and data across the entire product life cycle and uses insights about this data to automatically optimize the factory and all manufacturing processes" (Weber et al., 2017).

M2DDM presented challenges when attempting to gain accessibility to the maturity evaluation-based questions and formula. The inability to gain access to the procedure for evaluation and the evaluation-based questions ultimately prevented the model from being selected as the best-fitting model for the research. Dikhanbayeva et al. (2020) evaluated M2DDM and indicated that the "reports lack information about the model development methodology, as well as assessment methods". The lack of information pertaining to the model's development methodology presented challenges to the legitimacy of the research if adopted and was, therefore, not adopted for this research.

2.2.2 Maturity Model Selected for Research SIMMI4.0

Through comparing the possible maturity models available against the selection criteria, it was concluded that the System Integration Maturity Model Industry 4.0 (SIMMI4.0) would be the leading fit to be adopted as the maturity model for the research due to it fulfilling all four criteria for its selection. This is due to the model focusing primarily on SMEs I4.0 adoption within the application and IT landscape. This model additionally placed emphasis on the capabilities of evaluated enterprises regarding creating an I4.0 adoption roadmap. Additionally, SIMMI 4.0 was publicly accessible, making it possible to replicate in further works, and the authors of the maturity index were open to providing any additional supporting documentations.

The SIMMI 4.0 Maturity Index was able to fulfil all the criteria for the selection of the maturity model and, therefore, was adopted and integrated into the framework of this research. Further explanation on SIMMI4.0 and how it will be utilised within this research can be found in the chapter SIMMI 4.0 Maturity Index of this thesis; here, an overall outline of the maturity model is provided in extensive detail.

Maturity Models Evaluated for Research				
Name of Framework	**Accessibility to Maturity Evaluation-Based Questions and Formula**	**Focus on Manufacturing and I4.0**	**Application Centric Focus of IT Capabilities**	**Focus on SMEs**
SIMMI 4.0–System Integration Maturity Model Industry 4.0	●	●	●	●
ACATECH Industrie 4.0 Maturity Index		●		●
Digitalization Maturity Model for the Manufacturing Industry		●		●
Maturity Model for Industrial Internet		●		●
Maturity Model for Data Driven Manufacturing (M2DDM)		●	●	●

Table 2 Selection of maturity model

2.3 Previously Identified Barriers and Successes in I4.0 Adoption

Research into the field of successes and challenges pertaining to I4.0 adoption in SMEs has been conducted within a limited scope, relating to the focus of this research, indicating a need for further research. Current research exists to identify the drivers and barriers of I4.0 in SMEs throughout the context of different countries within their respective manufacturing sectors (Maisiri et al., 2021). Research within these fields identifies the conditions for promoting I4.0 adoption and the barriers which were faced during the adoption process. The current focus of research does not account for the successes within the adoption and transformation process but instead identifies challenges that are in relation to the initial drivers of the adoption process. The challenges which have already

been indicated within the field of I4.0 adoption will be identified and included to support further findings within this research. These challenges will be grouped based upon common themes, which will later be incorporated into the policy recommendation process.

The current literature pertaining to successes and challenges that have been published does not consider the policy objectives of the federal government but instead focuses on the initial driver for adoption. The currently identified barriers will act as supplementary barriers in I4.0 adoption, which will be determined through the conduction of interviews with experts and the case study. The themes of the barriers identified within the literature review will be classified based on the themes identified in the aforementioned data gathering methods, which will re-late to federal government policy.

The re-occurring themes, which will be determined through the literature review and the additional data gathering methods, will indicate crucial areas of focus for future policy. In addition, these re-occurring themes will indicate where and if there are any shortcomings in federal government policy which require greater attention. These areas will be indicated within the policy recommendation section of this research.

Research conducted by Müller, et al. (2018) examined I4.0 opportunities and challenges within Germany's manufacturing industry. The research conducted identified strategic and business model opportunities that promote competitiveness, enhanced efficiency, timing, flexibility, and quality as the driving objectives for I4.0 transformation within Germany (Müller et al., 2018). Furthermore, Müller et al. (2018) evaluated differences regarding varying company characteristics within the German manufacturing industry, which enabled the possibility to provide a greater scope. From the evaluation, the literature identified that the complexity of integrating I4.0 technologies was the encompassing barrier that German manufacturing identified in the I4.0 transformation.

Within the industry sector of mechanical and plant engineering, which directly relates to the machine tool industry, Müller et al. (2018) identified data security and transparency as a dominant challenge in I4.0 adoption. The mechanical and plant engineering industry sector, which M&Es are a part of, is a highly competitive market, and consequently, in relation to IIoT technologies and online platforms, the challenges of data security and transparency arise to hinder the I4.0 adoption process.

The mechanical and plant engineering enterprises evaluated within Müller et al. (2018) research indicated that the enterprises within this industry sector are "largely confronted with insufficient IT and software know-how due to their strong focus on hardware,

machinery and products". These challenges are responsible within the IT and application landscape of the organisations and are, therefore, within the focus of this research.

Müller et al. (2018) additionally established that both SMEs and particularly those within the mechanical and plant engineering sector do not demonstrate a significant negative relationship pertaining to challenges regarding organisational and production fit and I4.0 adoption, as do larger companies and those from other sectors. This revelation was indicated due to the higher flexibility and ability to respond to rapidly changing markets that SMEs possess. Additionally, the mechanical and plant engineering sector implements a long-term strategy typically on I4.0, which support future viability, thus limiting the micro-challenges which this sector faces.

Müller (2019) conducted research on identifying and assessing barriers in I4.0 from the perspective of workers, which provides a limited input within the literature on the relationship between the application and IT with employees. As a result, Müller (2019) identified four categories in which employees identified challenges parting to I4.0 adoption, which are within the sphere of the IT and application landscape.

The first challenge is that of "lacking competencies and know-how", which is a reoccurring theme from Müller et al. (2018), in which employees lack the IT-related competencies which I4.0 requires, that was not initially required in traditional manufacturing profiles. The skill set of employees this a continuous challenge identified in the literature pertaining to I4.0 adoption.

The second challenge identified is that of "lacking cooperation among departments" (Müller, 2019). The challenge of cross-department cooperation and integration provides a fundamental risk to I4.0, as one of the main pillars of adoption is that of horizontal and vertical integration (Leyh, Bley, Schäffer & Bay, 2017). The inability to exchange data and information across departments of an organisation prevents I4.0 transformation from taking place and thus indicates a weak point within the application and IT landscape.

The third challenge is that of "data access and protection", which directly relates to the fourth challenge of "availability of usable data", which are the fundamental challenges to the application landscape (Müller, 2019). The challenge these two identified categories present is that of the inability to promote interoperable systems and applications which demonstrate transparency. As identified by shop floor level employees, there is a challenge regarding data access and protection due to limited knowledge on the subject matter and different standards on the data being transmitted. Different standards for the transmission of data presents complications for enterprises that embark upon I4.0 adoption. For I4.0 adoption to be successful, data must be capable of being transmitted

with transparent standards to harness the greatest benefits. As for the availability of usable data, employees identified that the data being stored within enterprises are being stored based on “different standards, quality criteria and formats that they are stored in” (Müller, 2019). The result of the data storing operations requires reformatting of the data for each needed task, which blemishes one of the fundamental principles of I4.0, which is interoperability. The literature published by Müller (2019) provides an employee-centric view into the challenges which are faced pertaining to I4.0 adoption, which were not identified by management level. However, the emphasis of Müller’s research was the barriers from the workers perspective and thus, neglects the successes that workers could have identified.

Kagermann et al. (2016) conducted a study on the opportunities and challenges of cooperation between I4.0 leaders regarding creating standards and norms within the domain. The study was developed by Acatech and investigated the benefits of cooperation between domestic and international partners in Germany and abroad. The development of competency centres and new factories to serve as test beds for I4.0 implementation has provided German manufacturing with greater competencies and knowledge on deployment and interoperability (Kagermann, et al., 2016). The knowledge sharing within I4.0 development and I4.0 practises has serviced to aid in the standardization of practices, which is aimed at later enhancing the implementation of interoperable practises due to the common use of best practices, which were determined collectively (Kagermann, et al., 2016).

Interoperability between partners still presents an issue, particularly at the application level in which data transmission requires different standards and IT governance, particularly when looking outside the European Union, in which in-house developed legacy application systems present a great challenge for this. The implementation of the enhancement of interoperability, data security, and standardisation continue to present significant challenges within the IT and application field (Kagermann, et al., 2016). Additionally, the know-how for the technological implication of I4.0 is the overarching challenge, as although the aforementioned challenges can be identified, the skill set needed to address and resolve them on a large scale is not feasible. These identified challenges continue to contribute to the limitations of enterprises' IT and application landscape and, thus, hamper I4.0 transformation.

The successes and challenges identified from the literature review are presented in Table 3 alongside the authors and the focus of the research. The table provides a summary of the main points which were discussed within this subchapter of the literature review. The successes and challenges which were identified throughout the literature review will

be later compared against the results obtained to indicate where there are still reoccurring challenges and where new successes and challenges are presented.

Authors	Focus of Research	Successes	Challenges
Müller, Kiel, and Voigt (2018)	What opportunities and challenges support sustainable I4.0 adoption	▪ Organisational and production fit I4.0 adoption ▪ Long term strategy limits micro-challenges	▪ The complexity of integrating I4.0 technologies. ▪ Data security and transparency ▪ Insufficient IT and software know-how
Müller (2019)	Assessing the barriers to I4.0 implementation from a workers' perspective	N/A	▪ Lacking competencies and know-how ▪ Lacking cooperation among departments ▪ Data access and protection ▪ Availability of usable data
Kagermann, Anderl, Gausemeier, Schuh & Wahlster (2016)	An Acatech Study analysing the opportunities and challenges for cooperation and the current competition for the establishment of norms & standards	▪ Partnership advancement of I4.0 between business and society ▪ Establishment of new factories and a competence centre network modelled on I4.0 projects	▪ Interoperability ▪ Know-how for techno-logical implications of I4.0 ▪ Data security ▪ Standardization

Table 3 Barriers and successes to I4.0 adoption literature overview

3 Methodology

This chapter will describe and justify the data gathering methods utilised within the research conducted throughout this paper. The chapter aims to outline which specific data gathering methods were selected to be incorporated into the overall research and how they will support the research being conducted. The selection of the overall methodological approaches will be determined based upon a selection criterion and the most suited and best practices indicated for this specific type of research. The incorporation of the multiple methodological approaches throughout the research will be explained thoroughly and indicate how the maturity index and methodology support one another to investigate the overarching research questions.

3.1 Case Study Research Method Approach

This thesis incorporates the qualitative research method of a multiple case study approach to conducting an in-depth analysis of the current case of challenges and successes in attaining federal government policy in I4.0 adoption. The case studies will focus upon German machine tool enterprises, which are SMEs that are adopting I4.0 within their manufacturing process and will exclusively focus upon the IT and application landscape of the transformation. The case studies will work within the contextual framework discussed within the literature review portion of this paper. Case studies are regarded as the optimal research method approach when attempting to "illustrate what has been accomplished, worked well or which problems have occurred" (Großmann, Lehr, Lutz, Mönnig, Kleissl, 2016). The definition by Großmann et al. (2016) indicates why a case study approach will be incorporated into the research; as it will support in illustrating what has currently been accomplished within the I4.0 adoption of case study enterprises, while additionally indicating what worked well and what problems have occurred to provide policy recommendations. The case studies will work alongside the contextual framework of the maturity index SIMMI 4.0 outlined within the literature review section.

The case study approach will be beneficial to the conduction of this research due to its unique ability to turn respondents' observations into practical data (Großmann et al., 2016). Due to the nature of this research focus on obtaining observations from experts in the field of I4.0 and conducting an evaluation of I4.0 adoption, the inclusion of a case study approach will enhance the output of the data obtained from the initial conduction of the research. The variety of observations from respondents and participants in the research will support the case study approach as it will allow for the observations gained by these individuals to be incorporated into the finds and transformed into data that can later be used to support the drafting of policy recommendations.

The conduction of an exploratory multi-case study into a tool-machine manufacturing plant's IT and application landscape will provide rich data as "case study research represents a valuable research design in exploratory research" (Müller, 2019). Exploratory case study research would serve to be the best fit within this research and presents precedent due to it being "used successfully in information systems research, as represented by Industry 4.0 respectively the Internet of Things" (Dubé and Paré, 2003; Müller, 2019).

The case study procedure which will be conducted within this research is explained in Figure 5, which was extracted from the GIZ manual for practitioners, and provides a visual of the step-by-step process which will be followed (Großmann et al., 2016). This figure demonstrates how the case study approach will be conducted based upon the research question and case selection to perform data collection and a comparison in order to determine the findings for the policy suggestion.

Figure 5 Planning policy impact assessments, Großmann et.al (2016)

3.2 Data Gathering and Analysis

The means by which the data gathering techniques will be conducted will include employed semi-structured interviews, questionaries, and supporting documentation retrieved from the policy analysis review. These methods will be utilised to support the overall conduction to the case study to determine the challenges and successes for machine tool enterprises in I4.0 adoption in relation to government policy in Germany.

The first step of this research was to conduct an intensive policy analysis of supporting documentation pertaining to German federal policy on I4.0. Through understanding the previous positions of the government on I4.0 policy, and how they relate and support the current policy, it was possible to determine what the set of values of the government are and what they aim to achieve and attain in relation to the adoption of I4.0 practices in the German machine tool manufacturing industry. The information gathered in this stage supported the creation of questions for the semi-structured interview portion of this research. The semi-structured interview questions were designed to include questions pertaining to previous policy, current policy, identifiers of current challenges and

successes, and where enterprises currently are on the maturity model and where the government expects them to be. The questions were additionally designed to relate directly to each of the twelve questions, which are a part of the SIMMI 4.0 maturity model to ensure that there are expert answers to each of the questions in order to support the claims gained in the enterprise case study portion of this research.

The interview questions were sent to the interviewees prior to the conduction of the interview to ensure that the respondent was prepared for the questions and to familiarize themselves with SIMMI 4.0 prior. These questions targeted academics, professionals, and government employees, which will henceforth be referred to as experts, to provide a balanced response from those who directly interact with I4.0. The Semi-structured interviews will be conducted entirely online over video-calling methods. Once the data was gathered from the first portion, it was possible to conduct an analysis to determine what the government expects most companies to have achieved regarding current expectations. Additionally, it indicated where most companies score on the SIMMI4.0 level scale, which will be gained through the semi-constructed interviews with I4.0 experts. The guiding questions utilised during the interview and their relation to the three guiding research questions can be found in this paper's appendix under Interview Schedule and Questions.

The interviews conducted with experts in the field of I4.0 were recorded and later transcribed in verbatim. The transcriptions were initially transcribed by Otter.io, an audio transcribing system, and afterwards, the accuracy was checked by comparing the recordings with the transcription. Following the receiving of accurate transcriptions, the data analysis approach performed a thematic analysis of data to identify key themes within. The approach adopted allowed for the ability to identify the common themes of successes and challenges which were indicated by experts, which can later be adopted into the policy recommendation portion. The coding of interview data is a common approach adopted within previous literature surrounding I4.0 challenges and has been successful in identifying the overlying themes (Maisiri, 2021)

Experts, according to Meuser & Nagel (2009), are defined as “people who are responsible for development, implementation or control of solutions, strategies or policies”, additionally, they “usually have a privileged access to knowledge about groups of persons or decision processes, and have a high level of aggregated and specific knowledge, but also procedural, non-explicit knowledge that is otherwise difficult to access”. Therefore, experts will support this research further in determining the set aims of I4.0 adoption in Germany by complimenting the results obtained during the policy analysis section. The experts who will be consulted during the interview process will

come from government, academia, and professionals to provide explanatory, process, and technical knowledge in greater detail which is neglected in the policy. These results will complement the policy analysis portion in determining what was indicated as the main focal points of I4.0 adoption while additionally indicating possible neglected successes and challenges lost from the limited conduction of multi-case studies.

The experts from academia will be selected based upon their research into the field of I4.0 and relating fields and technologies. As for government officials, the research will draw from experts who operate or have operated within exclusively the federal government of Germany, its ministries, and organisations that operate on behalf of the federal government. As for professional experts, the selection criteria will be based upon operating within the ICT, manufacturing, or machine tool sector. These professionals must additionally have experience with I4.0 and its transformation within enterprises.

The semi-structured interview questions will be designed around addressing the main questionnaire questions in SIMMI 4.0 to provide expert guidance on these challenges that might be missed during the case study portion described later. Additionally, the interviews will provide an expert observation on what the federal government of Germany seeks companies to have achieved and where they are currently at regarding I4.0 adoption. The questions which will be asked can be found in the Appendix of this paper. Explorative expert interviews will be the means of the data gathering for this portion, as it will provide the ability to gain greater insight into challenges and success presented by experts and support better structuring of the research question at hand.

In Table 4, the expert interviewees who are consulted are listed. This table provides a redacted list of the experts interviewed to provide anonymity in relation to the occupation and identity. However, professional title and company characteristics are still provided to provide legitimacy to the answers provided in the interview. These interviewees were contacted via LinkedIn to determine their relation to I4.0.

Expert Type	Interview	Company Characteristics and Job Title
Academic/ Professional	Respondent 1	**Managing Partner:** Advisory organisation on technology and future technology policy
Academic/ Professional	Respondent 2	**Consultant:** Information Technology and services sector for German manufacturing
Government	Respondent 3	**Executive Assistant:** Government organisation promoting trade

Professional	Respondent 4	**Former Managing Director:** Leading Machine-tool sector enterprise
Professional	Respondent 5	**Managing Partner:** Enterprise focused on CRM systems in the application landscape.
Government	Respondent 6	**Head of Press:** Office of the Federal Government
Academic/ Professional	Respondent 7	**Professor and Lead Semantic Modelling & Applications Architect:** German University and German enterprise in industrial manufacturing

Table 4 Interview sample

The second data gathering step will be to provide questionnaires to the head of IT & application, I4.0, or digital transformation departments within the enterprises to conduct a case study to determine where the enterprises currently rank in relation to government expectations. The questionnaires will be administrated through google sheet and will utilise the questions initially incorporated in the initial publication of SIMMI 4.0, which were acquired from the authors of the paper. The questions will be administrated to the management level of the IT and digital transformation departments at the participating enterprises via a link. In addition, the managers of the IT and digital transformation departments will be identified via their profile on LinkedIn, which will allow for the ability to contact the participant directly and identify their role within enterprises. The questionnaire will consist of fourteen questions and will be answered entirely online in the German language. All the questions within the questionnaire are mandatory to complete to determine the overall maturity level in accordance with SIMMI4.0.

The practice of directing the maturity questions to exclusively the head of departments was incorporated by Acatech within the case study of their maturity model (Schuh, Anderl, Dumitrescu, Krüger, & ten Hompel, 2020b). The Acatech model adopts a holistic focus of the entirety of the enterprise under evaluation, and therefore, provides the questionnaires to the management head of each of the responsible sections. As SIMMI 4.0 focuses exclusively on the IT and application landscape, the questionnaires will be provided exclusively to the management responsible for IT and applications. This practice will allow for more accurate data on the enterprise, as the management level is responsible for identifying the challenges and successes and will be able to additionally provide a greater understanding of the challenges at large (Schuh et al., 2020b).

Following the completion of the questionnaires by the IT & application or digital transformation managers, a data analysis will be conducted based upon the steps outlined in SIMMI 4.0 to determine the organisation's overall maturity and the maturity stage of each section. The overall maturity level of the enterprise will then be graphed in a radar chart graph to be cross-compared to the maturity level which the government seeks to have attained and which experts expect most companies to be at currently.

Identifiable data gained from the maturity indexes will be kept anonymous within the research to not publicly identify challenges and strengths that participants from interviewed enterprises provided. This research aims to identify the challenges and successes faced by machine tool SMEs, which are gained from expert interviews and supported by the maturity evaluation, to provide policy recommendations. Therefore, the need to identify the companies to which participants belong is not required and will not weaken the research by removing identifiable data.

The answers gained from all the previous data gathering engagements will finally allow for the possibility of providing policy recommendations to the federal government to determine how the government can better support the machine tool industry in Germany with I4.0 transformation. The collection of data will support the policy recommendations, as through conducting a case study approach, it will have been possible to determine isolated challenges that are supported by not exclusively I4.0 experts but that of German enterprises in actual practice. At this stage, a further comparison will be conducted based upon the different challenges indicated by the experts and during the case study, while additionally indicating the similarities discovered based upon the results gained from the first and second portions of this research. These comparisons will allow for the possibility of accounting for the lack of an extensive case study base and indicate challenges indicated by both the experts and actual practice during the case study. Through this approach, the research hopes to limit neglected successes and challenges by incorporating two research approaches and incorporating various practical and academic expert input to gain as large as a variety of data on the subject matter.

The data sources and type of data which will be incorporated within this research can be examined in Table 5, which provides a summary of how each data gathering method will provide research results. The method of data gathering is listed following by how the method will further enhance the research practises.

Data Source	Type of Data
Policy Analysis	An analysis of previous and current policy surrounding and relating to I4.0 at the federal level in Germany
Semi-Structured Interviews	Interview questions based upon fundamentals of German federal policy surround I4.0 in relation to SIMMI4.0 maturity evaluation questions
Questionnaires	Quantitative rating of I4.0 and qualitative opinions provided by the management or executive leaders of I4.0, digital transformation, or IT and application landscape department of case study enterprises.
Observations	Compile overall results to provide a policy recommendation for the German federal government on how to support further successes and challenges in I4.0 adoption

Table 5 Data gathering methods incorporated into research

3.3 Selection Criteria for Enterprise in Case Study

The methodology which will be incorporated and utilized throughout this research will vary depending upon the research question being addressed. Overall, the research will utilize an exploratory multiple-case study approach that will determine what the federal government seeks to achieve in the adoption of I4.0 in the German machine tool industry; and determine what has currently been achieved through a case study approach. These selected case studies will provide a glimpse into the challenges currently being faced within the industry pertaining to I4.0 adoption and the successes, which can be investigated to provide policy recommendations further.

With the aim of conducting a case study, we followed the strategy of finding a representative sample (Yin, 2009, Eisenhardt and Graebner, 2007; Müller, 2019). The selection criteria for the enterprises to participate in the case study were determined based upon the principles that the company has already commenced upon I4.0 adoption, that the company is an SME, operated within the M&Es industry, and operates within Germany. These criteria were selected to fulfil the three research questions and maintain consistency throughout the evaluation. The case studies which were selected were then contacted through the IT, I4.0, or digital transformation department as they were the body responsible for the IT and application landscape which supports the I4.0 transformation which occurs.

The first requirement for participation was that the company had already commenced upon I4.0 adoption. This criterion was selected as although there can be barriers to the commencing of business processes transformation, the main focus was investigating the successes and challenges, and it would not be possible to determine any forms of successes without the previous adoption. The same argument can be made for not previously adopting I4.0 as without adoption, it cannot be possible to investigate the challenges of reaching the maturity level which the government seeks to have attained. However, it is essential to note that there can be challenges or barriers to entry for companies to begin on I4.0 adoption, yet this is not the main focus of this research.

The second, third, and fourth criteria are all directly related to the research question regarding the research's focal point. As the research focuses on SMEs within M&Es, it is critical that this is included within the criteria. The fourth principle is that the company must operate within and be registered as a German company. This principle was selected to ensure that the company can receive the support which the German government would suggest within its policy, as there are companies that operate within Germany which are not regarded as German and, therefore, will not directly make use of German policy, support and strive for expectations.

3.4 SIMMI 4.0 Maturity Index

This thesis will incorporate a variety of frameworks and approaches in order to address all three research questions. However, the SIMMI 4.0 Maturity Index will be an encompassing framework that covers the entirety of the research and research questions. This maturity model was selected in chapter 2.2 after comparing the maturity indexes to determine the best fit for the research. SIMMI 4.0 is a maturity index developed at TU Dresden to evaluate I4.0 adoption by assessing the current IT system landscape in selected enterprises. The maturity model was designed and intended for administration by enterprises and academics to conduct a maturity assessment to determine the As-Is and To-Be I4.0 transformation of the enterprise (Leyh et al., 2017). The models' design was developed to be simple to allow for the replication of transparent results. Although this model is designed primarily for determining the stage of I4.0 adoption, it will be incorporated alongside the results of the policy analysis to determine the stage of enterprises within German machine SMEs in I4.0 transformation to enable a comparison across the policy.

The maturity assessment conducted through SIMMI 4.0 is done through an entire evaluation of an organisation's IT and application landscape. The first point of evaluation begins with the four-dimensional landscapes of the enterprise or organization, which will be evaluated, and the assessment landscapes are represented in Table 6. These dimensions

will later indicate the areas of success and challenges which enterprises face, and provide a direct indication on where greater attention should be provided to improve the application landscape.

Assessment	Dimensional Landscapes of an Enterprise
I.	Dimension Vertical Integration
II.	Dimension Horizontal Integration
III.	Dimension Digital Product Development
IV.	Dimension Cross-sectional technology criteria

Table 6 SIMMI4.0 dimensional landscapes, based on Leyh et al. (2017)

The four-dimensional levels will be evaluated through fifteen questions provided to the enterprise's IT and application or digital transformation management level. Each of the fifteen questions will be responded on a scale of one to five, with one being no I4.0 and five being the highest level of I4.0 achievable. The questions provided in the questionnaire will additionally be taken from SIMMI 4.0 to maintain consistency in results, thus allowing for accurate comparisons. These results, once compiled, will be utilised to conduct a maturity level calculation using the formulas provided by SIMMI 4.0. The results gained through the formulas will then provide the enterprise's overall maturity level, which can be between levels one and five; these levels are outlined in the form of stages in Table 7.

Stage	I4.0 Transformation Stage
Stage 1	Basic Digitalization Level
Stage 2	Cross-Departmental Digitalization
Stage 3	Horizontal and Vertical Digitalization
Stage 4	Full Digitalization
Stage 5	Optimized Full Digitalization

Table 7 SIMMI 4.0 stages of I4.0 transformation, based on Leyh et al. (2017)

In accordance with SIMMI 4.0, Stage 1 would indicate a basic digitization level in which “The company has not addressed Industry 4.0. Requirements are not or only partially met” (Leyh et al., 2017). A maturity level of stage 2 would indicate a cross-departmental digitalization effort and that “the company is actively engaging with Industry 4.0 topics, and Digitalisation is implemented across departments” (Leyh et al., 2017). This stage would indicate that there has been an attempt to implement I4.0 requirements and is in the first stages. Stage 3 indicates that digitalisation has occurred both horizontally and vertically within the enterprise; and that I4.0 has been “implemented within the company, and the information flows have been automated” (Leyh et al., 2017). Stage 4 indicates that full digitalization has occurred within the enterprise “even beyond corporate borders and integrated into value networks” (Leyh et al., 2017). This would indicate that I4.0 is directly integrated within the corporate strategy of the organization. The final stage, or Stage 5, is optimised fill digitalization, which would indicate that the selected enterprise is a “showcase for I4.0 activities” (Leyh et al., 2017). This stage would indicate that the enterprise is a leader in I4.0 adoption within its industry and across industry lines and possesses a strong collaborative partnership with other organizations and networks.

The overall maturity stage level can only be determined once the results have been provided from the calculations. The answers provided during the questionnaire portion of the research will provide a selected value based on one to five of I4.0 adoption for each individual questionnaire question. The following formulas provided from SIMMI 4.0 can be viewed in Table 8. Once the level score is determined for each dimension, it is possible to calculate the overall maturity level (SIMMI Level) through adding the level score from each dimension and dividing it by four which is the number of dimensions. This result will, in turn, provide the overall maturity level of the enterprise’s I4.0 adoption being evaluated; thus, allowing the possibility of further evaluation of the challenges and successes which enabled the enterprise to attain the provided level.

Dimension	Formulas	Question Results (QR)	Level Score
Vertical Integration (VI)	$VI = \left(\frac{QR2.1 + QR2.2}{2}\right) \times \frac{1}{5} + \left(\frac{QR2.3 + QR2.4}{2}\right) \times \frac{4}{5}$	QR2.1 = QR2.2= QR2.3= QR2.4=	VI =
Horizontal Integration (HI)	$HI = \frac{(2 \times QR3.1) + QR3.2}{3}$	QR3.1 = QR3.2=	HI =
Digital Product Development (DPD)	$DPD = \frac{QR4.1 + (Combined\ QR4.2\&4.3)}{2}$	QR4.1 = QR4.2&4.3 =	DPD =
Cross-sectional Technology Criteria (CTC)	$CTC = \frac{QR5.1 + QR5.2 + (3 \times QR5.3)}{5}$	QR5.1 = QR5.2 = QR5.3 =	CTC =
Overall Maturity Level	$SIMMI\ Level = \frac{VI + HI + DPD + CTC}{4}$	Overall Maturity Level =	

Table 8 SIMMI 4.0 evaluation and calculation formula Leyh et al. (2017)

The SIMMI4.0 calculation will provide the overall maturity level for the enterprise being evaluated based upon the IT and application landscape I4.0 capabilities. As SIMMI4.0 is a maturity index, it was initially designed by Leyh et al. (2017) to allow participating enterprises to compare their desired state of transformation against their current state. However, for the purpose of this research, the desired state of transformation will not be included within this dissertation; instead, it will replace the desired level of transformation with that of the expert indicated German SME average and government expected level for comparison. The comparisons will allow for the indication within the IT and application landscape where there are successes and challenges currently being faced and how the successes and challenges relate to each other due to their connection between dimensions.

4 Guiding Policies and Aimed Outcomes for I4.0 Adoption

Within the literature view sector of this research, a policy analysis was conducted to evaluate the overall development of I4.0 policy within Germany. The present federal policy surrounding I4.0 has been a continuous progression of ICT and manufacturing policy with links to social policy surrounding education and employment. The literature review of previous federal government policy, linked to I4.0, has provided the groundwork to determine the dominant and reoccurring themes throughout the policy releases and what themes are currently sought to have been attained by German enterprises. Furthermore, the policy analysis allows for the possibility to determine what are the overlying stated guiding policies and aimed outcomes, whereas the interviews conducted with experts will allow for the underlying aimed outcomes to be revealed and indicated in the research.

The most present policy concerning I4.0 implementation within Germany at the time of publishing is that of the 2030 Vision for Industrie 4.0 Shaping Digital Ecosystems Globally, which was analysed within section 2.1.7 of this paper in greater detail. The three main fields of action of this policy are autonomy, sustainability, and interoperability. These three fields of action are the main focal points in which the federal government seeks enterprises to achieve within the guidelines of I4.0 by the year 2030. The 2030 vision was published by Plattform Industrie 4.0, which is the overarching body for publishing I4.0 policy and recommendations within Germany.

The current 2030 vision for Industrie 4.0 has been developed through combining details and concepts from previous policies related to I4.0. Through combining previous policy, the current policy seeks to ensure that there is a strong foundation to move forward with the integration of I4.0, as the preceding policy was developed around commencing implementation. In contrast, current policy is about integrating what has already been implemented. To ensure a successful integration of I4.0 across different sectors and actors as indicated in the 2030 vision, there must moreover be a strong implementation foundation; therefore, the current policy includes components of preceding policy upon which it has been built up upon.

To provide a clearer understanding of the previous policy, a literature review and policy analysis of preceding federal policy were conducted within this research, and in Figure 6, the main focuses of previous policy development related to I4.0 are outlined. This figured demonstrates how technology, ICT, and manufacturing policy transitioned into what would become I4.0 policy as a whole. The figure presents each policy's main points, which was analysed to determine what the overall objects were.

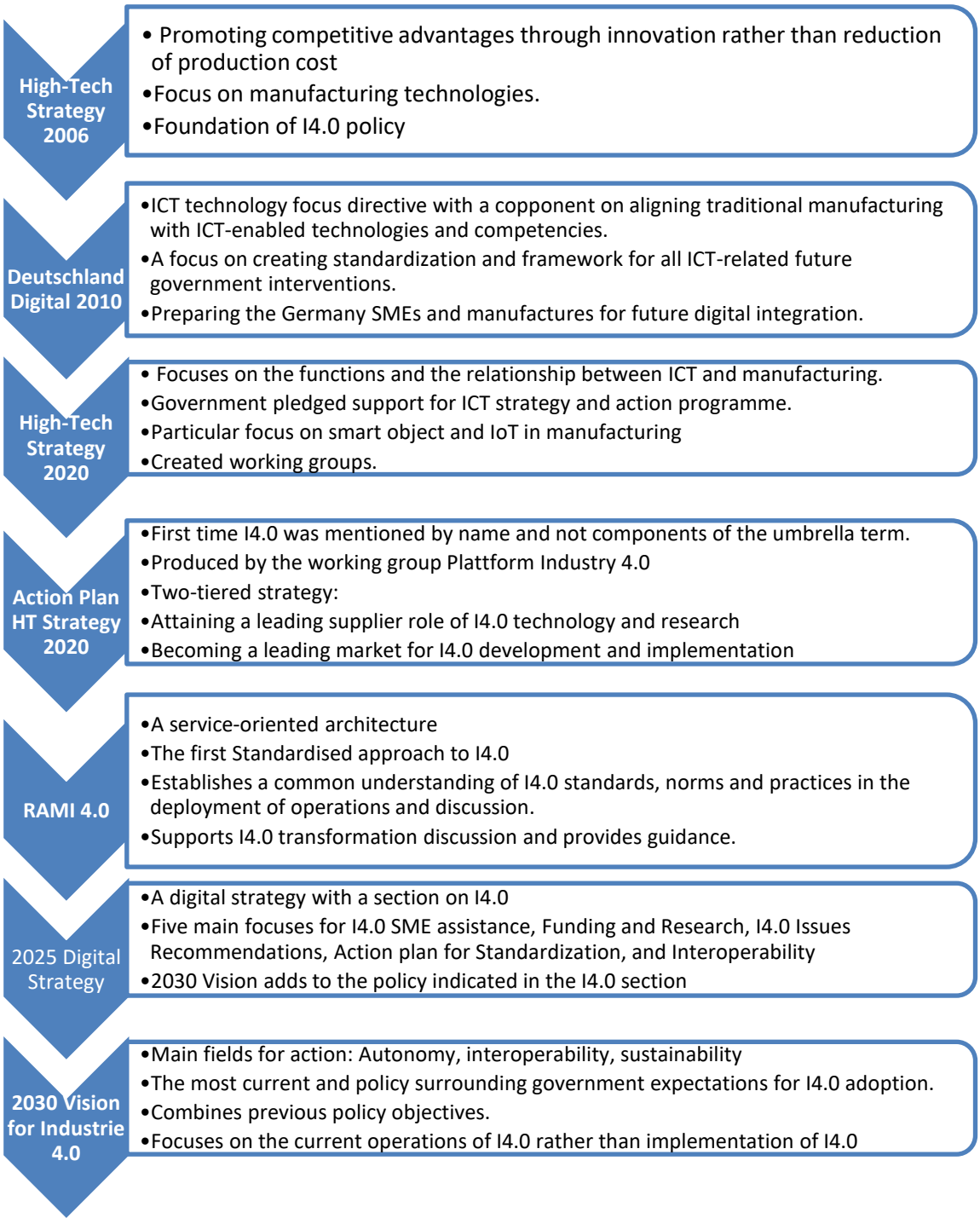

Figure 6 Main findings of policy analysis

The aimed outcomes of previous German policy are indicated in Figure 6. The previous policy was developed for ICT, manufacturing and technology, which would later be combined to formulate I4.0 policy. Previous German policy and its aimed outcomes within the aforementioned fields were continued in I4.0 policy, and the support for these projects and transformations are still readily available. As the current I4.0 incorporates the same objectives that the previous policy sought to achieve, it is possible to infer that

there have been challenges in the adoption and transformation of I4.0, due to the notion that the policy continues to incorporate the same or transformation similar objectives.

4.1 Guiding Policies and Aimed Outcomes Indicated from Policy Analysis

The research which is being conducted focuses upon the most current federal government policy at the time of publication, which is the 2030 vision for Industrie 4.0. The aforementioned 2030 vision is broken down into three main fields of autonomy, interoperability, and sustainability. These three main fields of actions were selected due to the relationship within the adoption processes between each of them, which is that the adoption of one field of actions supports later adoption in the other. These fields of action operate in conjunction with one another, which provide the basis for the integration of I4.0 implementation. As such, they are the leading focuses that are sought to be implemented in German SMEs.

The three fields of actions contain sub-implementation processes, which supports the directive in its adoption process. The sub-implementation objectives are identified as objectives that contribute to the overall main fields of action, which can be referred to as aimed outcome of which is to oversee the integration of I4.0 capabilities. The sub-implementation processes are themes that are aimed to be achieved within the overall policy objective of the main field of action and are regarded as the main objectives which the federal government seeks SMEs to attain.

The main fields of actions and the sub-implementation processes were investigated during the policy analysis portion of this research in chapter 2.1.7 in greater detail. The policy analysis of the 2030 vision for Industrie 4.0 identified the key policy focuses on which the federal government seeks for enterprises to achieve. The key areas are the main fields of action, and the sub-implementation processes are the steps to achieve the aimed outcome. The sub-implementation processes were analysed within the policy analysis section to identify the key themes within the guiding policy.

The key themes of the guiding policy for I4.0 in relation to the main fields of action are broken down in Table 9 to provide a comprehensible breakdown of the underlying federal government policy. Within this table, it is possible to indicate what sub-implementation process belongs to the main field of action of the 2030 vision for I4.0.

2030 Vision for Industrie 4.0	
Main Fields of Action	**Sub-Implementation processes**
Autonomy	▪ Digital Infrastructure ▪ Safety and Security ▪ Technology Development
Interoperability	▪ Standards and Integration ▪ Regulatory Framework ▪ Decentralised systems and Artificial Intelligence
Sustainability	▪ Decent Work and Education ▪ Social Participation ▪ Mitigating Climate Change

Table 9 The breakdown of the current guiding policy's aimed outcomes

4.1.1 Targets for IT and Application Landscape Innovation

The IT and application landscape were not the focal point of the 2030 vision for Industrie 4.0 policy but rather were contributing focus points within the sub-implementation processes of the main fields of action. Within each section of the sub-implementation process, there were targets indicated for adoption for the IT and application landscape of I4.0 directed at adopting enterprises. The German federal government, although not specifically mentioned by name the focus of the IT and application landscape, however, did indicate focus points for adoption to attain the desired progression of the policy. These focus points directly relate to the IT and application landscape, as they require attention within these landscapes to achieve the overall objectives of the policy.

Through conducting a policy analysis of the current policy surrounding I4.0, it was possible to deduce what were the targets for the IT and Application landscapes within. The IT and Application landscape are the foundation of any current digitalised enterprise due to its task of supporting the physical business process through applications and IT infrastructure. Consequently, the policy encompassing I4.0 is aimed at the digitalisation of SMEs; therefore, the policy must present targets and objectives for attainment with the field of the IT and application landscape.

The 2030 vision for Industrie 4.0 is broken down based on the main fields of action, the sub-implementation processes, and the targets for both the IT and application landscape (see Table 10). This chart simplifies the aims of the policy for both the IT and application landscape based upon the sub-implementation processes of each main field of action within the 2030 vision. The results harnessed from analysing the 2030 vision policy will serve to provide indicators that will support the evaluation of the current trajectory of machine tool SMEs in the implementation of I4.0 in relation to the aimed outcomes of

the policy. Furthermore, these results provided in provision with expert interviews and the results gained from the case study conducted with SIMMI4.0 will determine where the overall successes and challenges are regarding I4.0 adoption and implementation.

2030 Vision for Industrie 4.0			
Main Fields of Action	**Sub-Implementation Processes**	**Target for IT Landscape**	**Target for Application Landscape**
Autonomy	Digital Infrastructure	Implementation of autonomous infrastructures	Implement application software which promote accessibility
	Safety and Security	Implement backup and recovery infrastructure for data protection and security by design	Autonomous permission for data usage
	Technology Development	Further integration with application landscape	Dynamic integration of application and digital business models supported by IT landscape
Interoperability	Standards and Integration	Integrate I4.0 IT standards for current and future integration	Integrate I4.0 application standards for current and future integration
	Regulatory Framework	Integrate governance rules and data autonomy	Integrate governance rules for transmission of data across stakeholders
	Decentralised systems and Artificial Intelligence	Decentralised, autonomous systems which further cooperation, transparent use	Provide new solutions and business models. Further interconnection of machine and user data
Sustainability	Decent Work and Education	Proactively promote training for IT landscape employees	Proactively promote training for application landscape employees
	Social Participation	Additional IT infrastructure to support communication between stakeholders (B2C)	Enable greater communication and dialogue between stakeholders through applications
	Mitigating Climate Change	Additional IT infrastructure to support product life cycle maintenance and monitoring	A design-based approach which enables applications to limit material waste

Table 10 Targets for IT and application landscape relating to guiding policy

The targets for the IT and application landscape which were deducted from the 2030 vision for I4.0, provide an indication of what German M&Es, SMEs must achieve to progress with I4.0 transformation regarding government objectives. These objectives indicated in the "Target for IT landscape" and "Target for application landscape" category of Table 10 can be classified as key performance indicators (KPIs) of I4.0 policy that are required to achieve transformation regarding government objectives. These objectives will be compared with the results gained from the conduction of semi-structured interviews with I4.0 experts to determine if any additional underlying objectives were missed during the policy analysis.

4.2 Guiding Policies and Aimed Outcomes Indicated by I4.0 Experts

The main overarching themes indicated in the 2030 vision provide a precedent on what the aimed objectives are in I4.0 adoption. However, there are additional aims that are desired based upon the conditions of industry, sector, and the size of the enterprise. Through conducting semi-structured interviews with experts in the field of I4.0 from the private and public sector alongside academia, it was possible to determine what are the main objects based upon the coding of interviews. The input provided by experts in the field enabled the possibility to evaluate what the federal government seeks M&Es, which are SMEs to have achieved and what has currently been achieved regarding I4.0 transformation.

The interviews with experts provided additional knowledge on I.40 in general while simultaneously delivering information specific to the IT and Application landscape and the machine tool industry related to I4.0. Through conducting expert interviews, it was possible to verify the aimed outcomes of federal policy based upon experience from working in the industry and with federal policy.

The expert interviews shed light on the relationship between enterprises and the knowledge pertaining to federal policy on I4.0. Out of the seven expert interviews which were conduct six of the respondents were able to identify that they had previous knowledge of federal policy on I4.0, and two respondents were able to indicate knowledge of Bundesländer (State) policy pertaining to I4.0 (See Appendix 11B). The responses regarding knowledge of federal and state policy were also vague, as most respondents indicated that there are policies. However, the experts were not aware of their content and aimed objectives, as only two respondents could identify the content and aimed objectives officially stated (See Appendix 11B). These results indicate that there is an apparent lack of engagement and promotion of policy on behalf of the federal government to share and indicate their interests, which is reflected with the Digital Strategy 2025 policy, which focused on promoting I4.0 further (BMWi, 2016).

The lack of federal policy knowledge was additionally reflected when interview question three was asked, which focused on whether enterprises account for federal policy when implementing I4.0. The result of this interview question reflected that the majority of German SMEs which are in the M&Es industry do not account for federal policy when engaging with I4.0 adoption as four respondents indicated that enterprises account for the policy, and three indicated that policy is occasionally considered, but only after their interests, customer interests, and then finally federal interests (See Appendix 11B). When pressed further on why or why not enterprises account for federal policy, when implementing I4.0 adoption, the most pressing themes were financing indicated by seven of the respondents, KPIs by five of the respondents, and influence by four of the respondents.

The theme that arose the most that contributed to a positive consideration of federal policy surrounding I4.0 transformation was financing. The theme of financing refers to government funding for enterprises to participate in research and development projects and that of global cooperation projects. From the expert interviews, it was possible to determine that federal financing was a driving factor for knowledge of federal government objectives, which was due to the funding being provided based upon conditions set in place by the federal government. Experts indicated that enterprises that cooperate with the federal government on projects understood federal objectives greater than those that did not.

The theme of KPIs within the coding of these interviews refer to the ability of I4.0 to provide heightened performance capabilities. Experts indicated within the interview process that the initial driving force for I4.0 adoption is that of the ability to increase KPIs. I4.0 is primarily adopted due to its ability to increase effectiveness and efficiency within the manufacturing process to provide a competitive advantage to the enterprise and increase profits. The aims of the company implementing I4.0 are surrounded around economic profitability, and therefore, federal policy is not the initial incentive to adoption.

The theme of influence provides both a positive influence on knowledge pertaining to I4.0 policy. Influence refers to the influence that the federal government possesses on the industry within the country. Experts indicated that Germany's leadership role in I4.0 globally encouraged companies to further I4.0 adoption and became stakeholders in policy development through working groups. The ability of an enterprise to be a part of working groups and unions which develop policy on I4.0 presents a unique ability for enterprises to engage with the system and encourage greater understanding of government objectives.

The one of the greatest challenges pertaining to the federal policy surrounding I4.0 adoption, which experts indicated, was the increased need for financial support for development and adoption. Out of the expert interviews conducted four respondents indicated a greater need for financial support, one as partly needed, and two as the current support is fine (See Appendix 11B). Financing was a common challenge that federal policy lacked regarding IT and application adoption due to the expensive adoption cost and the focus on ICT technologies rather than applications. Additionally, building in house applications increase the cost attributed to I4.0 adoption. Financing from the federal government can mitigate the cost and risk attributed to the adoption process and thus encourage additional adoption in enterprises. Additionally, funding can be utilized to support greater adoption. As previously indicated by experts, the practise of I4.0 transformation to achieve level five full digital optimization is limited by financial restraints. One means of resolving this barrier is by providing tax incentives which provide tax reduction based on each new level of I4.0 adoption attained in relation to federal policy objectives, and a large long-lasting incentive for achieving level five. Financial incentives are the driving force for I4.0 adoption, therefore, they should be utilised to encourage greater knowledge of federal policy on the subject matter, while also serving to encourage and revamp the transformation which has encountered barriers in the adoption process. This position was particularly supported by respondent two:

> "*I think then there's a big part of the financial incentive or the financial benefits, if companies can, let's say, take the investment of their taxes or get a big tax return if they implement in a specific way. That would certainly I think, have more of an impact than just a paper stating, oh, we want to be the market leader*" (Respondent Two)

The challenge of a lack of a skilled workforce was additionally indicated by six expert interviews (See Appendix 11B). Vocational training within the field of I4.0 implementation, particularly in the IT and application landscape, is limited and presents a challenge, more so to SMEs and specifically M&Es. SMEs and M&Es present a larger challenge to access a skilled workforce due to the geographic location of manufacturing facilities within Germany. SMEs, which are M&Es, are predominantly located within southern Germany, particularly in remote locations, making it difficult to attract a skilled workforce than if the enterprise was located in a more populous city. This challenge was expressed in particularly greater detail by respondent one who elaborated on the particular challenges within access to a skilled workforce in Germany.

> *"when you look at especially new jobs, like a data scientist, those people are not available everywhere. Of course, you get them. You can hire them when*

> *you're working close to Köln, or if you're based in Hamburg or whatsoever. But when you are somewhere on the countryside, of course, it's tough to get the right people. And when we look at some in the manufacturing industry, a lot of them are somewhere in more or less remote locations." (*Respondent One*)*

The geographic challenge was raised throughout expert interviews when the challenge of a lack of a skilled worked force arose. The responses directed at limited access to a skilled workforce is complemented in the 2030 vision for I4.0 policy which seeks to tackle this challenge by promoting constant life-long learning.

Isolated data silos were additionally a challenge indicated by experts within the field of I4.0, and those that work directly within the IT and application landscape field. Data silos refer to the "segregated group of data stored in multiple enterprise applications" (Patel, 2019). Data silos directly present challenges to business operations and decision-making while being directly opposed to the aims of interoperability indicated within the 2030 Vision. Out of the expert interviews conducted, six indicated that data silos present a significant challenge within the IT and application landscape in regard to progressing with I4.0 transformation (See Appendix 11B). Data silos occur due to incompatible data systems with the architectural layer, which transpires due to the utilisation of multiple application systems which require specific features and tools to support business users; thus, when transferring data between applications, processed data is no longer accessible (Patel, 2019). As I4.0 is developed upon the principle of data-driven manufacturing, the inability to access, process, and transfer data presents a significant threat to the future transformation efforts and of current operations. Data silos can thus result in poor decision making and negatively impact profitability (Patel, 2019).

The challenges of data silos occur to a greater extent when examining the relation with IIoT devices such as sensors. IIoT devices are implemented within I4.0 transformation to allow for greater access to constant data, which can be transmitted from the sensors to the data warehouse and then forth to the application system, enabling data analysis and analytics to occur. When data silos occur, particularly in relation to IIoT devices (CTC dimension), it is crucial that data is transmitted transparently across all dimensions of the enterprise to enable accessibility of data to support decision making and operation processes. Additionally, the transmission of data autonomously serves to enhance the effectiveness of decisions and operations. However, data silos in relation to IIoT devices severely limit I4.0 transformation and reduce the overall efficiency of operations and the abilities of application systems to provide success.

Data security and privacy was an issue raised by experts; however, the results significantly differed from that of the federal government. The federal government indicates that data privacy and security governance is a concern that ought to be addressed within Germany; however, only two experts shared similar views with the federal government (See Appendix 11B). Instead, four of the expert interviewees indicated that current data privacy restrictions at the federal level and that of the European level are limiting the progress of I4.0 and its capabilities (See Appendix 11B). The four respondents did not share the same concern of data privacy as the federal government due to two differing perspectives, which are that either third party application systems such as SAP or Microsoft have built-in data governance which complies with data privacy regulations. The second is that the information being transferred at the manufacturing level do not need to necessarily account for citizen privacy as they do not operate with this form of data, and just provides additional costs for operation. Additionally, the one expert who partly shared concerns with the federal government pertaining to data security and privacy was not directed at individual data protection, but data security for protecting machine technology from international competitors with the ever-greater push for interconnectivity (Respondent Four).

> "*With the concern of data security and privacy more be in regard to protecting from competition domestically and internationally, rather than digital privacy of consumers, and, and the individual*" (Respondent Four)

Reshaping the role of IT departments, was identified by experts as a particular area of focus that can support greater I.40 transformation within performing enterprises. Five of the experts indicated during the interview process that IT departments in many SMEs still contribute to exclusively support business operations in the traditional sense (See Appendix 11B). IT departments are not involved within the transformation process or within digital manufacturing; therefore, currently working within the guise of data security and maintenance tasks. Experts expressed a greater need to integrate the IT departments within the digital manufacturing processes as this will ensure strong transformation efforts and effective implementation of application systems.

> *"As we perceive it, the I.T. departments are still treated as a classical office, I.T. departments, meaning they are taking care of all the processes taking place in the offices, but they are not so much involved when it comes to processes more on the manufacturing level. So, what we see here is that this is usually more in the hands of the production, so people who in the past worked on automation topics, they are now in charge of industry or at least for those technologies that are close to the shop floor."* (Respondent One)

Implementing an “interface between the office IT department and the production company” will need to be ensured for future initiatives to be successful (Respondent One). Therefore, this aspect is a crucial area of focus to ensure greater roles and responsibilities of the IT department within the integration of digital manufacturing processes. Increasing the responsibilities and contributions of the IT department within the digital transformation process will enhance the effectiveness of the transformation process, and the digital business processes as a whole as it will ensure greater integration of operations along the IT and application landscape. Within the architecture of the enterprise, each interface should be evaluated for bottlenecks and weak points for connections, as it is commonly identified as a challenging aspect within digitalization efforts which was identified by respondent five:

> *“where companies fall down nowadays is architecture. They have all these different systems that don't talk to one another, and then in order to get any value out of things, they have to build interfaces, and interfaces are very expensive. And every interface is a weak point. It's something that can go down”* (Respondent Five)

Standardization was a challenge identified within all of the expert interviews, as was interoperability (See Appendix 11B). Standardization presents concerns to exerts both on an international level and within Germany. Although experts expressed the concern of standardization, the majority of them expressed confidence that Germany would successfully overcome this challenge, as it is currently a global leader in this regard. As for interoperability, this was expressed as a challenge moving forwards due to the current lack of standardization which has been met on an international level. Without a clear definition of global stands, global interoperability cannot feasibility be implemented as the implementation of such relies on a concrete foundation.

> *“International supply chains require alignments in terms of international standards and requirements to have those technical equipment’s alongside with clouds and so connected altogether. In this case, Germany is with its advantage in the development of these industrial standards well equipped to negotiate these standards to become mutually accepted. There the German government also finances certain international cooperation projects with important partners worldwide to align on these matters.”* (Respondent Three)

5 Level of Maturity Attained in German Machine-Tool Industry Case Studies

This section of the research paper will focus on providing the results gained from the maturity level of SIMMI 4.0 evaluations on the IT and application landscape of selected German machine tool enterprises. The SIMMI4.0 evaluations will be presented as separate case studies to provide practical IT and application landscapes examinations. The case study results indicated within this chapter were gained through administrating questionnaires to the respective heads which are responsible for digital transformation or IT and application landscape of the enterprise. The results gained from this chapter will shed greater information on the practical challenges and success which SME M&Es are facing in Germany pertaining to I4.0 adoption and the respected level of maturity which has been attained in relation to SIMMI4.0 criteria.

5.1 Case Study One

The first case study performed a maturity evaluation based upon the SIMMI 4.0 principles on a machine tool enterprise that is a leader in its field of industrial technology production. The enterprise has commenced upon the digital transformation of its operations and integrating its systems to provide competitive advantages since 2018. This enterprise's maturity level was evaluated within the I4.0 development department. Henceforth, for anonymity purposes, this organisation will be referred to as *M&E manufacture A* to differentiate between the other case study, which will be referred to as *M&E manufacture B.*

5.1.1 M&E Manufacture A Results

The results attained from the questionnaire distributed at *M&E manufacture A* indicated that the enterprise is a leading actor in I4.0 adoption and transformation through the attainment of the overall maturity level of 3.05, which was rounded to 3. The maturity evaluation indicated a strong I4.0 adoption and digital transformation in three out of the four dimensions in relation to government I4.0 expectations. These results provide an enhanced understanding of successes within the machine tool industry pertaining to the adoption and transformation stages of I4.0.

Within the *Vertical Integration* (VI) dimension, *M&E manufacture A* received an overall level score of 1. This score indicates that on the VI- dimension, the enterprise substantially underperforms in relation to government expectations. The evaluation identified a significant lack of application integration throughout the business process, which is intended to support the enterprise's operations. The significantly low score within this dimension demonstrates that there are current challenges being faced by M&E

SMEs regarding integrating application systems that support corporate planning and control within the digital transformation process. Thus, in accordance with SIMMI 4.0, this score indicates that the procedure model and development process of *M&E manufacture A* within the VI dimension demonstrates the characteristics of:

> *Integration of enterprise systems only department-specific. The enterprise systems along the enterprise's value chain only support their respective fields of activity* (Leyh et al. 2017)

Within the *Horizontal Integration* (HI) dimension of the evaluation, *M&E manufacture A*'s level score was 3.5, indicating an above-average integration in relation to other German M&E SMEs and slightly below government expectations. The level indicated for government expectations was four, which in relation to the current results of *M&E manufacture A* indicate that the enterprise is on the verge of achieving set expected results. The level of 3.5 can be rounded to 4, as the enterprises present greater characteristics of level 4 than level 3, thus indicating that the enterprise demonstrates a "continuous cross-corporate integration in value networks" (Leyh, Bley, Schäffer, & Forstenhäusler, 2016). This score and characteristic more accurately reflect the level which M&E manufacture A demonstrates within its manufacturing process. Additionally, these attributes relate directly to the main objective, which the federal government seeks SMEs to implement within the IT and application landscape through the main field of action interoperability in the 2030 vision (Plattform Industrie 4.0, 2019a).

In the *Digital Product Development* (DPD) dimension, *M&E manufacture A* received an overall level score of 3.0, which indicates that they are below the expectations of the federal government in the I4.0 transformation, which is level 4. However, they are around the level which experts indicate most SMEs are at. This level indicates that "product development is continuously digitally supported" (Leyh et al., 2016). However, to achieve the level of attainment sought by the federal government, the enterprise would need to adopt an approach that digitally forwards product development information beyond corporate levels (Leyh et al., 2016).

As for the *Cross-sectional Technology Criteria* (CTC), the level score was that of 4.2. This level of achievement indicates that the organisation did surpass the level of attainment which the federal government sought in I4.0. The CTC dimension, which was the most substantial level of maturity that the organisation received, particularly was in relation to question 5.3 of the questionnaire, where the organisation ranked extremely high regarding data privacy and security. Additionally, cloud applications and the incorporation of big data solutions within business operations proved to provide not solely enhanced business opportunities but increased the overall ranking of the enterprise within

its maturity evaluation. In accordance with the SIMMI4.0 score, this level indicates that the enterprise demonstrates the characteristics of:

> *Service-oriented cloud-based platform. Services are offered for the partners in the value networks. Information and data are exchanged in real-time along the supply chain. Optimization of the entire production through Big Data solutions. Access to data is protected. Cross-corporate encryption of data and authentication for global access.* (Leyh et al., 2016)

The high level which was received in the CTC dimension is primarily due to the extensive incorporation of technologies that provide big data, primarily sensors within the machine production. These sensors directly provide extensive information to the application landscape pertaining to servicing, maintenance, and processes provided by the CNC machines. However, when comparing the result to the VI and HI dimension, it is clear that the information flow is not autonomous, transparent, and interoperable; therefore, although the information is transmitted, the full extent of the value is not reached, and greater value could be harvested from the CTC dimension if more extensive development in other dimensions was to occur.

5.2 Case Study Two

The SIMMI4.0 evaluation questionnaire was distributed to the Application/Technical department at *M&E manufacture B*, which was answered by the head of the department. *M&E manufacture B* is an SME, which specialises in the production of parts for tool and die mould manufacturing which supplies the aerospace, automotive, and micro-technology industries. The enterprise is regarded as a leading technology and service provider in the machine tool industry and operates both internationally and domestically in Germany. The enterprise has already begun the digital transformation process since 2017, which sought to implement I4.0 as a principle of its operation to enhance connectivity and efficiency to electrical discharge machining (EDM) processing. Therefore, the strong presence of I4.0 with this enterprise should serve to provide valuable insights into the direct challenges and successes which have already been indicated throughout the implementation process.

5.2.1 M&E Manufacture B Results

The results from the SIMMI4.0 maturity evaluation conducted on M&E manufacture B provided an insight into the challenges which are currently being faced in regard to I4.0 adoption. The enterprise was unable to achieve the desired expectations of the federal

government in any of the four evaluated dimensions, and within the overall maturity level. The case study demonstrated that there are currently direct challenges for leading machine tool enterprises with the integration process of the application landscape. The enterprise performed poorer than that of *M&E manufacture A*, in three of the four dimensions, however, both under performed in relation to the average level of M&Es and that of government attainment.

Within the VI dimension, the second case study obtained an overall level score of 1.6, indicating that the enterprise is on the higher end of VI and is working towards attaining level 2. However, much like the first case study, case study 2 faces shortcomings in regard to the integration of enterprise systems due to their department-specific isolation. Within this field, only basic digitalisation levels have occurred, and I4.0 requirements are not being met, as the ability to exchange information from machines to different levels of the enterprise are not possible.

As for the HI dimension results, M&E manufacture B received its highest-level score, which was 3.125. This level indicates that much like case study 1, information flow has begun to be automated and can be realized within the business value network. The results obtained indicate that interoperability is possible and current in practice across different value networks. These capabilities are related to the 2030 vision, as they enable the ability to perform interoperable data exchange; however, they lack the extent to which the policy aims to achieve which is international. The process of autonomous data flow is feasible and can be achieved however, it is indicated that the greatest challenge to the success of this is the foundation of application systems which allow for it.

DPT dimension of the evaluation indicated a level of 2, which demonstrates that the enterprise has commenced upon I4.0 within this field; however, the main challenge is that data and information exchange is not automated. The lack of automated data exchange indicated that there is a gap between capabilities and policy expectations within the main fields of action autonomy and interoperability of the 2030 vision. The capabilities challenge the digital infrastructure, and regulatory framework sub-implementation processes, due to the inability to exchange information autonomously, thus indicating a specific area of challenge that policymakers should focus on.

As for the CTC results, the enterprise evaluation received a level score of 3, indicating that the enterprise is still below the expected level score within this field but is in the midst of progressing towards the desired level. The production within the enterprise is continuously adjusted and optimised in real-time, providing the groundwork needed for greater integration of AI systems. However, the enterprise lacked the integration of cloud abilities throughout the business process, providing difficulty for the transmission of data

between fields. Yet, regarding IT security, the enterprise utilises an advanced security model, in which access to data is continuously protected through the adoption of encrypted data transmission. The IT security evaluation indicated that within the IT landscape, there are limitations due to the lack of cloud adoption for backup and recovery; thus, the infrastructure is lacking; however, the capabilities of the enterprise still perform well with the lack of needed infrastructure. Therefore, IT security is also an area in which the 2030 vision policy is not fully attained, and emphasising the autonomy of safety and security should be enhanced.

The maturity level calculations based on the answers received from M&E manufacture A and M&E manufacture B can be viewed in Table 11. These results are based upon the answers received from the questionnaires sent to the responsible management level, which were then evaluated utilising the SIMMI 4.0 evaluation formula. Within Table 11, it is possible to compare the results between both case studies across dimension level scores and the overall maturity level.

Dimension	Case Study 1 Level Score	Case Study 2 Level Score
Vertical Integration	1	1.6
Horizontal Integration	3.5	3.125
Digital Product Development	3.5	2
Cross-sectional Technology Criteria	4.2	3
Overall Maturity Level	3.05 ≈ 3	2.43 ≈ 2

Table 11 Cross comparison of case studies, based on Leyh et al. (2017)

The data obtained from the SIMMI 4.0 surveys can be retrieved in the Appendix of this dissertation to provide the initial scoring data for each dimension, and how the overall level score was determined. This data is in the form of the initial surveys provided by both anonymous case studies.

6 Gap Analysis of Case Study Results and Government Expectations

Through conducting interviews with experts, it was possible to determine both SIMMI4.0 overall maturity level for German federal government expectations and the average level that SMEs have attained in I4.0 transformation. The SIMMI4.0 maturity model provides a basis for evaluating the IT and application landscape of I4.0 transformation and indicates where the evaluated enterprises are within these landscapes. The experts who were interviewed indicated that the SIMMI 4.0 overall maturity level, which the federal government seeks to have achieved, is 4.2, which is rounded to 4. As for the average level attained by the majority of SMEs, the level of 2.5 was determined, which was rounded to 3. The SIMMI 4.0 definition of the overall maturity which the federal government seeks SMEs to have attained is:

> *The company is completely digitized even beyond corporate borders and integrated into value networks. Industry 4.0 approaches are actively followed and anchored within the corporate strategy.* (Leyh et al., 2017)

As for the overall maturity level, which is the average level that SMEs have achieved, according to the results provided by experts in the field, the SIMMI 4.0 definition is:

> *The company is horizontally and vertically digitized. Requirements of Industry 4.0 have been implemented within the company, and information flows have been automated.* (Leyh et al., 2017)

The overall maturity level for M&E manufacture A is 3, which indicates that digitalisation has been conducted horizontally and vertically. This is one level below the desired adoption level of the federal government and on par with the average level of adoption of SMEs in Germany. The SIMMI4.0 definition of this transformation is:

> *The company is horizontally and vertically digitized. Requirements of Industry 4.0 have been implemented within the company, and information flows have been automated.* (Leyh et al., 2017)

As for M&E manufacture B, an overall maturity level of 2 was provided, which indicates that digitalisation has been in operation, exclusively cross-departmental. This level achieved is below the average level of SMEs in Germany by one, and two below the government expectation level of adoption. This achieved level indicates that there are currently a variety of challenges being faced by the enterprise pertaining to I4.0 adoption. The SIMMI 4.0 definition of this level of transformation is:

The company is actively engaged with Industry 4.0 topics. Digitization is implemented across departments and first Industry 4.0requirements are implemented throughout the company. (Leyh et al., 2016)

Within Figure 7, a gap analysis of the results across the dimension of SIMMI 4.0 evaluation can be seen to provide a visual of the gap in adoption. Within this visual, it is possible to view that out of all four dimensions, only one case study performed above government expectation, in one dimension, which was within the dimension of CTC, indicating that the enterprise's I4.0 transformation has exceeded government expectations within the dimension. As for the other three dimensions, the enterprises fell below government expectations. The greatest challenge in I4.0 adoption was in the VI dimension, where both M&E manufacture A and B severely underperformed both government expectations and the average level; thus, indicating that policy should focus on greater support within this area. However, M&E manufacture B particularly fell below government expectation in all fields, and evidentially more in the VI and DPD dimensions.

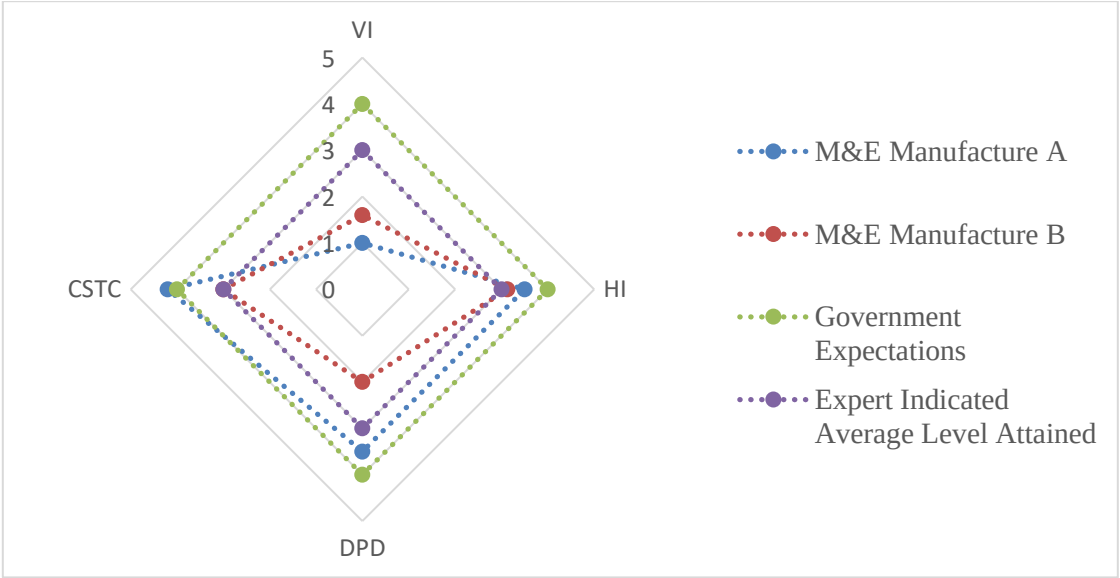

Figure 7 Gap Analysis of Results

The gap analysis indicated that there are currently greater challenges within the adoption process of I4.0 in German M&Es, within the IT and application field. The results of the case studies indicate there is a disparity between government expectations and the reality which is currently in practice. The IT and application landscape are the foundation for successful I4.0 transformation as they will support the digital operations of manufactures; therefore, the gap dictates that further adoption which does not address these fields will only serve to fail in future areas as there is a lack of supporting landscapes. Federal policy in Germany surrounding I4.0 adoption requires already

implemented digital practices within the enterprise's IT and application landscapes, which was determined by both the policy analysis portion and supported by the level of maturity which was indicated by I4.0 experts. As policy already expects that previous adoption has occurred, German M&Es SMEs will continuously fall short of the intended level of attainment without the proper guidance.

Although the case studies fell short of the government intended levels, they additionally occasionally fell short regarding the average level of SME attainment in Germany within the dimensions. The level indicated by experts as the average level of attainment for SME I4.0 adoption was the overall maturity level; therefore, the case studies can indicate within the average maturity level which dimensions are the greatest challenges in the transformation process. As both case studies either surpassed, underperformed, or were par with the average level of attainment, it is possible to indicate specifically the dimensions that present significant challenges and thus be included within the policy analysis portion. These dimension areas which require the greatest focus in future policy are DPD, and more so VI. A comparison of the case studies shows that the average level of adoption and government expectations across dimensions and overall maturity level can be examined in a bar graph in Figure 8.

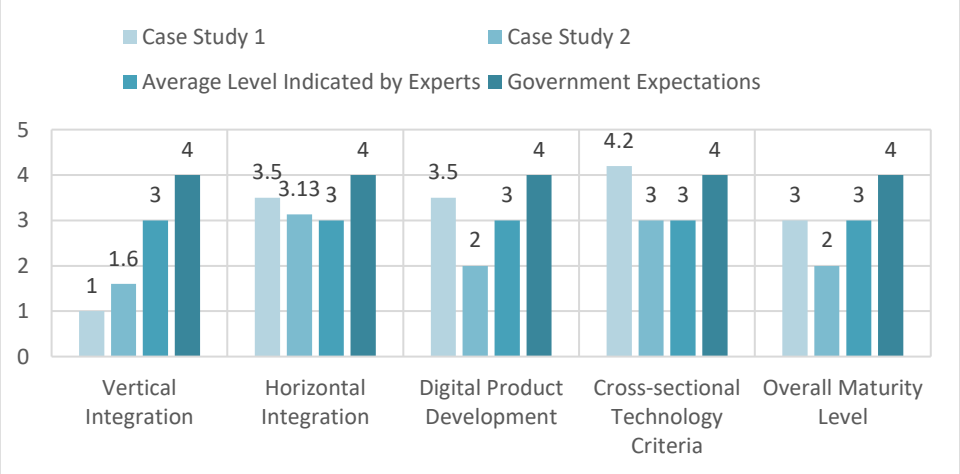

Figure 8 SIMMI 4.0 analysis results in bar-graph format

7 Policy Recommendations

The policy recommendation, which was determined from the results of expert interviews and the conduction of multiple case studies, is directed at the German federal government, the supporting ministries, and working groups which develop the I4.0 policy on behalf of the federal government. The recommendations included within this portion were determined through the conduction of the research into the successes and challenges which German M&E SMEs are currently confronting. The successes indicated from the conduction of the overall research and the results gained from the case studies should be noted to support I4.0 within Germany further. The challenges indicated by the experts and replicated further within the analysis of case studies should be addressed with the purpose of supporting higher quality I4.0 transformation.

Although the focus of this research has been directed at M&Es, which are SMEs, the results can transverse across different industries and sizes of enterprises. As the M&Es, which are SMEs, can be regarded as the centre or heart of the German economy, the lessons gained from this research can proliferate to support further policy development and I4.0 transformation within Germany, and therefore, should be considered to strengthen the German manufacturing sector. Furthermore, the indicated areas of challenges from the gap analysis should indicate in which dimension German policy should attribute greater support and focus on supporting I4.0 adoption.

The overall level of maturity indicated by experts that the federal government would seek for SMEs to have achieved regarding I4.0 adoption was not surpassed by the case studies conducted, indicating a gap between the desired progression and the current as-is state of enterprises. The gap between the two demonstrates that there is currently a lack of directed support at areas of challenge and replication of best practices within the industry. To support German SMEs to achieve the desired level of attainment, federal policy should adapt to include the findings indicated within this research.

The largest area in which struggling occurred for M&E SMEs was that of the vertical integration dimension, which evaluated components from the lowest to the highest level of the enterprise, in which physical products exchanged information between levels. The first case study adopted a strong organisational approach; however, the lack of integrated application systems which supported operations within the I4.0 transformation is the Achilles heel for further integration. The questionnaire results within this section of analysis provided a low score exclusively on the application systems; however, when examining the highest maturity level achieved, the cross-sectional technology dimension could determine why a low initial evaluation was received prior.

The enterprise which was evaluated indicated a low level within the vertical dimension due to its relationship with its maturity level in the CTC dimension. The enterprise exceeded government expectations in the CTC dimension in case study 1, as it was a leader in its field for technology development, with a strong emphasis on IT security and the utilisation of a variety of technologies across departments. The IT landscape within this regard demonstrated enhanced capabilities; however, the strong technology adoption created challenges within the application landscape. The continuous development of technologies limited the ability to interconnect and exchange information, particularly information and application systems which are compatible across the company. The challenge of integrating I4.0 technologies is due to the complexity of its nature, and was a previous challenge indicated by Müller et al. (2018); thus, there is a greater need for focus on support in this area as this challenge is still replicated within the findings of this paper. Therefore, the enterprise faces extreme difficulty in maintaining its vertical integration and thus, provided challenges for interoperability.

However, the challenges within the vertical integration dimension were additionally experienced by case study 2, to a lesser extent. The second case study did not face the same challenges due to a lower score in the CTC dimension, as the organisation managed to keep up with the integration requirements, as they did not over exceed their capabilities. Thus, a balance between the VI and CTC dimension is required to provide optimal transformation and should be focused on simultaneously as a means of best practice and to receive the greatest degree of benefit from the transformation.

The VI dimension was the lowest-achieving level of maturity attainment within the case studies and is thus the greatest point of concern. The development of future German policy surrounding I4.0 should place emphasis on supporting vertical integration, as it prevents the current goal of enabling autonomous transparent data-driven tactical and strategic decision making. The exchange of information thought the vertical level limits the capabilities of the physical products, particularly the machines within the M&E industry. Expert interviews predominantly disclosed that information exchange practices are currently conducted by the transmission of excel sheets through email across departments in most SMEs. The transmission of information within these practices furthermore requires the information to later be converted to different formats when there are different enterprise application systems, thus, severely hampering the effectiveness and abilities of the enterprise. This practice should be a primary focus to be undertaken by the guidance of federal policy, which can serve to provide greater benefits to enterprises. The adoption of a standard application system per enterprise will enhance the transmission of autonomous data and support the transformation process.

A common theme that arose during the interview process with experts was that of integrating application systems from one supplier. A challenge that enterprises face pertaining to the application landscape is the integration of a variety of applications from different suppliers and that of legacy application systems that were developed in house. Experts indicated that a wide variety of SMEs developed in house application systems to support their business operations, and thus the implementation of new systems and enterprise transformation can ultimately rework the entry of the business process. Implementing application systems from one supplier would benefit SMEs in the long term, as it would reduce the operation, development, and maintenance cost of the systems and accelerate digital transformation to support new forms of I4.0 technologies such as augmented reality and AI.

Augmented reality and AI systems are a focal point of current federal policy surrounding I4.0 adoption under the autonomy and interoperability section of the 2030 vision; therefore, the implementation of standardized application systems can support the adoption of this objective. The adoption of augmented reality can support M&Es with the service and maintenance performances, allowing for remote support through virtual service technician experts. This objective would fall within the fourth and fifth stage of SIMMI4.0 yet can be rapidly achieved by adopting third-party application systems such as Microsoft and SAP, which both develop application systems to support I4.0 transformation and develop ICT to collaborate with the systems. The implementation of third-party application systems to support the enterprise would significantly enhance the capabilities and effectiveness of enterprises, as in-house developed application systems present future challenges and barriers for interoperability and maintenance; additionally, it would require the in-house application know-how to remain at the enterprise for service, connection and maintenance. Therefore, German federal policy should consider partnering with third-party application system suppliers to promote the purchasing and adoption of standardised application systems. This will allow SMEs to become more competitive by gaining access to application systems to support their operations at lower cost and average to higher-end efficiency yield. The implementation will allow SMEs to compete at a higher level with larger and global enterprises and reduce the challenges they face within the foundation of I4.0 adoption.

One policy suggestion which was particularly indicated by respondent four and supported by other experts, and the case study research was the development and deployment of an application systems from a third-party supplier. It is suggested that the federal government partners with an enterprise, particularly SAP which is commonly utilised by German manufactures, to develop an application system and module that supports the federal government I4.0 objectives (Respondent Four). Future I4.0 funding

can be spent supporting the development of such a program, which would suffice in ensuring a proper transformation within the IT and application landscape and thus support future interoperability and current standardization efforts. Particularly, in addition to this, it will reduce the initial costs of developing in house application systems (Respondent Four). The development of an application system, which includes an I4.0 module, can be co-developed by Plattform Industrie 4.0, SAP, and the federal government, which would ensure that the application and IT landscape of enterprises would meet the requirements and level needed to attain the objectives within federalI4.0 policy. The co-development of such a project would be the quickest means of resolving the challenges of I4.0 transformation within eh IT and application landscape. Such an application system and module would additionally support the possibility of greater standardization of I4.0 practices and enable streamlining interoperable practices once more significant implementation, and adoption of the co-developed application occurs. The possibility of interoperability can become a reality due to the majority of enterprises implementing the same application systems which are developed for the specific purpose of promoting interoperability in the value chain.

The conduction of interviews with experts indicated a reoccurring challenge within the evaluation process, which was that the optimised full digitalisation level (level 5) is not the most optimised level for all enterprises. Full I4.0 transformation is an ideal that the federal government seeks to implement across Germany, and many companies would desire to have; however, the overall financial cost for such a transformation customarily does not provide the same cost-benefit for each SME. Adopting or implementing new applications and IT systems within enterprises can provide operational successes and achievements within the adopting enterprises; however, the lack of operational knowledge is still a great concern.

Experts interviewed shared a mutual concern pertaining to access of skill-based employees to operate and maintain new systems across Germany. This challenge arose due to most SMEs operating in Southern Germany within remote areas, making it difficult to gain the high-skilled labour needed to operate I4.0 systems. Additionally, many companies that implement new IT and application systems claim I4.0 leadership or expect that the IT and application systems will produce results autonomously. This notion was expressed by the majority of experts interviewed, as the IT and application systems are designed to support operations and not acts as a holistic solution. Therefore, future policy should focus on addressing these misconceived perceptions and provide indications on how digital transformation within these areas can reap more significant benefits for enterprises, though collaboratively supporting different functions and areas of operations within manufacturing enterprises.

In different sectors and processes, the traditional means for production can provide more revenue and efficiency that might not be gained through digitalisation efforts. This challenge must be considered when developing policy and promoting I4.0 transformation, as there cannot be a one-size-fits-all approach for SMEs and within differing sectors. Rather level five I4.0 policy should account for enterprises that are on the larger end of SMEs and large-sized enterprises as there is greater access to the resources required, such as R&D funds and the skill-base to implement.

It was identified with expert interviews, predominantly those that are professionals, that I4.0 provides a tremendous advantage for the M&E sector due to the high-tech machining that is required to produce precise machinery and equipment. The market of the M&E sector requires precise and high-tech products to operate and manufacture; therefore, it is possible to see greater advantages within this sector, thus encouraging greater adoption. Digital transformation and implementation can be encouraged on a greater scale in the M&E sector; thus, the best practices observed within this sector can be recognised and adapted to be replicated within other sectors.

Digital transformation and I4.0 adoption differ depending on the enterprise which is commencing the process. The challenges and successes of this process particularly differ depending on if the enterprise is brand new and emerging in the field or if the enterprise has been around for a long period of time and has cemented itself within its traditional business processes. This is important for policymakers when drafting policy, as many enterprises within Germany have been around for a long time. Long-lasting enterprises face different IT and application landscape challenges pertaining to I4.0 transformation, particularly regarding home-developed application systems. When the older etherises attempt to transition their application systems which were home developed, many of the legacy systems were not developed properly or are intertwined with processes and operations as they were customized. This challenge does not occur for new enterprises which implement vanilla or customised application systems from larger suppliers. As this thesis indicated that the majority of German enterprises are still on a lower level of I4.0 adoption, at level three, future policy should still consider the beginning phases once more and provide tailored guidance towards both groups, as SMEs particularly consist of both long-lasting and newly formed enterprises.

The future policy can concentrate less on data security and privacy, as the results obtained from the maturity analysis and the answers obtained from experts pertaining to the subject matter indicated that M&E SMEs have already adopted robust data security and privacy framework is implemented into everyday operations. Müller et al. (2018) and Müller (2019) indicated that data security and transparency were common issues within

the adoption of I4.0. However, since publishing these results, it is possible to conclude from this research that this topic has been extensively addressed by enterprises and needs less guidance on the matter.

Kagermann et al. (2016) indicated that standardisation was a common challenge experienced within I4.0 transformation. This challenge has become less prevalent with greater I4.0 adoption. Current I4.0 adoption trends normally include outsourcing the transformation process to consulting companies, which has enhanced the standardization approach due to knowledge of common practices and the utilisation of RAMMI4.0 as a reference for the architectural transformation. The challenge of standardisation was not replicated within the research conducted within this paper, as the enterprise results indicated that standardisation practices have already begun to occur. Standardisation is extremely important in relation to interoperability, and therefore, it should continue to play a role within future policy to ensure that newly occurring practices are addressed; however, the prevalence which standardisation continued in previous policy should not occur in the updated version unless they address standardization at an international level in which German industries present a leading role which experts indicated.

The organisational and production fit of I4.0 adoption and the long-term strategy which M&E SMEs demonstrate are still reoccurring successes within the field and thus should continue to be replicated. The ability of SMEs to address micro-challenges has been extremely beneficial in leading the way for new practice within I4.0 in their field due to the ability to address micro-challenges which limited impact on the business processes. Future I4.0 policy should promote individual I4.0 strategies for each enterprise to implement, which will help guide enterprises seeking to engage with the transformation process and act as a form of road map for the transformation process. The strategy should incorporate the standards of RAMI4.0 to ensure future interoperability. Additionally, including a greater role and responsibilities for IT departments within enterprises should be incorporated in I4.0 strategy to encourage greater participation and internal integration.

Table 12 outlines the successes and challenges which were determined within the literature review portion of this research and are cross-compared against the research results of this paper. The previously identified successes and challenges identified within the I4.0 transformation were compared to determine whether the results were replicated or not within this research; thus, determining the new sets of challenges and successes faced, particularly in the M & M&E industry.

Authors	Successes	Challenges	Research Results
Müller, Kiel, and Voigt (2018)	1. Organisational and production fit I4.0 adoption 2. Long term strategy limits micro-challenges	3. The complexity of integrating I4.0 technologies 4. Data security and transparency 5. Insufficient IT and software know-how	1. Replicated 2. Replicated 3. Replicated 4. Was not replicated 5. Replicated
Müller (2019)	N/A	▪ Lacking competencies and know-how ▪ Lacking cooperation among departments ▪ Data access and protection ▪ Availability of usable data	1. Replicated 2. Replicated within the vertical dimension, not the horizontal 3. Was not replicated 4. Replicated
Kagermann, Anderl, Gausemeier, Schuh & Wahlster (2016)	▪ Partnership advancement of I4.0 between business and society ▪ Establishment of new factories and a competence centre network modelled on I4.0 projects	▪ Interoperability ▪ Know-how for techno-logical implications of I4.0 ▪ Data security ▪ Standardization	1. Replicated 2. Replicated 3. Replicated 4. Replicated 5. Was not replicated 6. Was not replicated

Table 12 Result comparison with previous literature

The replicated challenges indicated by this research, and which are presented in Table 12, were further expanded upon within this section of the research. The policy recommendations expressed within this section are summarized in Table 13, which indicates the policy focus, which is the theme of the recommendation which was determined through expert interviews, and the conduction of a maturity index. The policy focus is then explained in summary under *detail* which can then be compared against the column *Indicated in Vision 2030*. The latter column indicated whether the policy recommendation can fall under a current main field of action and its sub-implementation process or if one does not exist yet.

What Should be Incorporated in New I4.0 Policy		
Policy Focus	**Detail**	**Indicated in Vision 2030?**
Education	Greater know-how is needed to maintain and operate the IT and application landscape. Particularly M&Es face a greater gap in IT knowledge due to their focus on machining parts.	**Sustainability**: Decent Work and Education

	Thus, future policy should support and encourage greater training	
Vertical Integration/ Autonomous Data exchange	A greater need for vertical integration is needed, as autonomous transparent data-driven tactical and strategic decision-making cannot be achieved. Additionally, data flow between departments and the digital to the physical world is hampered by limited success. A focus on greater integration is needed to achieve the desired progression and can be enhanced through standardized application systems, and a balance with CTC as the technology being developed needs to be able to be supported by the application landscape. Standardized application systems co-developed by the federal government and a third-party can support this objective.	**Autonomy**: Digital Infrastructure **Interoperability**: Decentralised systems and Artificial Intelligence
AI and Augmented reality	Augmented reality systems should be promoted within the CTC dimension of the IT and application landscape, as it will enhance the capabilities of SMEs in the M&E sector. Augmented Reality can be low cost to acquire and integrate into the operations and be supported by incorporating standardized application systems. The adoption and incorporation of such technology will level the playing field globally for German SMEs, particularly in the M&E industry, allowing for the possibility to virtually support servicing machine tasks	**Interoperability**: Decentralised systems and Artificial Intelligence
Level of Value; Funding and Financial Incentive	Each enterprise that commences upon I4.0 transformation should identify which maturity level of adoption would serve to provide an actual cost-benefit for the transformation. Future policy should provide greater funding for transformation processes at higher stages, such as 3 to 4 and 4 to 5, as the cost for such transformations is exceptionally high on the upper stages, and the value acquired is more limited for SMEs. Therefore, if policymakers desire higher adoption levels, then policy should provide more significant project funds. The practices of incentivising I4.0 transformation in relation to government policy can encourage greater knowledge of policy and influence the transformation process. Providing large tax returns based on each new I4.0 level adoption which is determined by government maturity evaluation, should be considered to encourage greater adoption. While also large long-term tax incentives for attaining levels 4 and 5, the cost for attaining such levels is exponentially higher than acquiring other levels and will support	Does not exist but can support the entire 2030 Vision policy objectives

	reducing the current roadblock in I4.0 adoption, which is to stop at level 3 or 4 due to the cost-to-profitability of the transformation. This approach should be greatly considered as it will encourage a holistic adoption and aid in striving towards achieving digitalization of markets which is the long-term objective of the federal government.	
Approach	The I4.0 adoption and transformation approach should be drafted differently based upon the type of industry considering the transformation. Newly established enterprises will face fewer challenges within the adoption and transformation process, as their business processes, practices, and IT and application landscape will be newly established; therefore, the integration challenges will not be met or met at a lower degree. Whereas long-established enterprises will face challenges with transforming and integrating legacy systems. The policy should consider developing a two-tiered strategy to support this	Does not exist
Greater Participation	Participation and communication between B2B and B2C have continuously provided successes to the I4.0 transformation process and should continue to be practised and emphasized. Incorporating customer use data will enhance the ability of the enterprise to adapt operations and products to better support customers' needs and business partnerships. Additionally, the working groups and sharing challenges and best practices within the field has enhanced the adoption process by supporting the speed at which transformation occurs. The communication network between unions, government, academics, and enterprises should continue as it provides Germany with a competitive advantage	**Sustainability**: Social Participation
Long-Term strategy and Production fit	Long term strategies for the I4.0 transformation process have enabled the possibility to identify challenges that occur fast to be resolved. The long-term strategy ensures that the integration of IT and application systems occurs and does not face faulty integration difficulties. Long term strategies should be encouraged in future policy to support a long-lasting I4.0 transformation in Germany.	Does not exist
Role of the IT department	The policy should consider placing a greater emphasis on the IT departments of enterprises to incorporate them within the entirety of the business process. Currently, IT departments contribute within a traditional sense and are neglected from the digitalisation efforts; thus, greater integration of	Does not exist

	roles and tasks will support the maintenance and digitalisation efforts of the entity of the enterprise.	
Co-developed Application systems and I4.0 Modules	Policymakers should seriously consider Co-developed application systems and I4.0 modules. Participation between stakeholders relevant in I4.0 has been successful in the past, and greater participation within the IT and application landscape can further support this. A standardized application system can ensure that federal policy objectives are incorporated while ensuring that a durable application landscape has been implemented. This suggestion can reduce the barrier of financial costs for enterprises to embrace transformation within the IT and application landscape while at the same time ensuring that standards are implemented, and a quick transformation occurs. Additionally, it would support future transformation efforts, interoperability at the domestic level, and potentially global levels, which will support a smoother transformation process.	It does not exist but can support: *Interoperability*, *Autonomy*, and *Sustainability; particularly the standards and integration sub process*

Table 13 What should be incorporated in future I4.0 policy

8 Limitations

As the research conducted throughout this paper was an exploratory multi-case study approach, there are possible limitations to the overall scope. The first limitation can be in relation to the scope of the research in which exclusively the IT and application landscape was focused on in SME which were M&Es. As the scope became extremely narrow, the overall policy recommendations cannot serve as an overall answer to the challenges currently facing I4.0 as a whole but rather can exclusively address these within its field. This can challenge the overall benefits of policy recommendations; however, as initially indicated at the beginning of this research paper, I4.0 is a large and encompassing topic that connects many different actors within a business process. Therefore, it was necessary to exclusively focus upon a narrow scope for the research to provide the leading policy recommendations on isolated challenges and successes.

Another limitation of this research was the limited number of case studies that were conducted. This was a challenge to overcome, as many possible participating enterprises were more interested in research being conducted on their business operations rather than research being conducted which would more predominantly benefit the federal government in policy recommendations. This challenge was enhanced by the actuality that many enterprises and experts in I4.0 were unaware of any suggested government expectations, policy, and support. The limitation from the limited use of participants for the case studies would attempt to be reduced by the incorporation of interviews with experts in the field of I4.0, which provided additional views into the barriers and successes faced with I4.0 adoption and transformation. These experts provided legitimacy additionally to the results obtained from the case study, as they complimented the results or provided supplementary insight into challenges which not exclusively the case study enterprise was facing. Thus, providing both academic and expert input to complement the physical on-ground research obtained.

As I4.0 has begun to transcend national borders, a greater scope of enterprise operations should be considered. This research focused on isolating the specifics of enterprises within the German economy to evaluate I4.0 adoption; however, many SMEs conduct operations on a multinational scale. Therefore, further investigation of an enterprise as a whole could serve to enhance the research as it is possible that the operating location evaluated was outdated compared to other locations. Therefore, evaluating the operations of enterprises as a whole could serve to provide greater data on the challenges and success within the IT and application landscape as these would need to be connected across global departments.

The data gained from experts came from the first-hand experience within the field of SMEs, M&Es, I4.0 transformation, and the IT and application landscape. The recommendations and suggestions provided by experts on how to deal with the challenge of I4.0 transformation within the IT and application landscape can at best be regarded as areas of the future focus on adoption practices. The recommendations and suggestions provided should be evaluated individually to determine the overall feasibility and successes if they were to be pursued further. The policy recommendations are based upon a small anonymous sample size that identified key areas within the IT and application landscape that require further policy attention and was supported by expert experiences and knowledge within the field. To better determine if these key areas are of value to further examine, the policy recommendations should be compared against the KPIs of enterprises and that of the federal government's aims.

The quickest means of resolving the challenges of I4.0 transformation within the IT and application landscape, which was promoted within the policy recommendations portion of this dissertation, was that of partnering with a private third-party supplier of application systems such as SAP. The co-development of an I4.0 module between the federal government, Plattform Industrie 4.0 and an enterprise such as SAP would enable the possibility of standardisation and ensure those policy requirements can be met as a sound application landscape is implemented in relation to federal policy. However, the limitation of implanting such a project would first require the federal government to re-evaluate their policy objectives and properly determine what application systems are required to support the aims of *sustainability*, *autonomy*, and *interoperability* indicated in the 2030 vision (Plattform Industrie 4.0, 2019a). Additionally, the development of an I4.0 application system would not benefit larger sized enterprises and would focus predominantly on SMEs. Thus, this project would require a larger scope of focus to include both SMEs and large-sized enterprises to ensure interoperability throughout the entirety of the value chain. A project of this size could require a significant amount of funding from the federal level but would ensure that the future I4.0 transformation efforts would not be limited due to a weak IT and application landscape.

9 Conclusion

The current German I4.0 policy is aimed in the right direction in regard to advancing the digitalisation of the manufacturing sector to reach optimal attainment. However, the federal government's level for enterprises to achieve does not correlate with the level that enterprises are currently at. The current federal policy seeks to have German enterprises attain the optimal level of I4.0 adoption and does not provide solutions to achieve these objectives. For I4.0 policy to be more successful, the policy ought to provide solutions and greater support; otherwise, enterprises will continue to lag behind. Additionally, the federal policy should account for greater considered of the current situation in which enterprises are at and their technological capabilities to support such desired transformations and implementation of technologies.

This research was able to determine that there is a large gap between the current as-is state of German SME M&Es and the to-be state, which the federal government seeks for adoption. The research was additionally able to determine areas where enterprises are currently experiencing significant challenges in the transformation process. The IT and application landscape of case study enterprises and the results obtained from discussions with experts indicate that these landscapes are the backbone of I4.0 transformation. The significant challenges preventing further adoption from occurring are due to limitations located within these areas. The federal government must re-design current policy to indicate where there are greater challenges occurring and provide support to transform the entirety of the IT and application landscape within many German enterprises. If I4.0 transformation continues without re-evaluating and ensuring a formidable transformation within these landscapes, then the future adoption wither and the possible value obtained from I4.0 will not be relevant.

The enterprise readiness of I4.0 transformation based upon the maturity evaluation and the expert interviews continue to indicate that there are significant gaps between the current level of attainment and the desired level of progression. German enterprises significantly lack behind within the IT and application landscape, which can be predominantly attributed to legacy in house systems, non-interoperable systems and applications, and non- integrated vertical and horizontal dimensions. In order for an enterprise to achieve the desired level of adoption, there needs to be significant information systems architecture re-designing at the IT and application level, as currently, the enterprises are far behind in the IT and application landscape to achieve what is sought of them.

The policy recommendation listed in chapter 2.1 seeks to provide areas of focuses for future policy. Current I4.0 is developed around the principles of autonomy, sustainability, and interoperability; these objectives can be met, however as indicated by previous policy, time is a factor that will determine the plausibility of such developments. Keeping in mind the concern of time which was indicated within all previous policy that was in relation to I4.0 and was analysed within this dissertation, that for Germany to maintain its role as a global leader in I4.0, transformation must continue to occur at a rapid pace. Therefore, the policy recommendations considered the factor of time, and that is why the suggestion of partnering with a third-party application supplier was indicated.

The partnering with a third-party application supplier such as SAP will support Germany's global role as a leader in I4.0 due to its ability to provide a rapid solution to the application challenges while integrating the principles of the federal policy. The co-deployment of such an application system will additionally enhance the knowledge and relevance of federal policy, which was previously identified as being unknown by experts, and enable the possibility for German enterprises to resolve the challenges of their application systems within a rapid and relevant manner. The co-development of such an application and modules is the pillar of the policy recommendation, which will provide instant results within the industry, while the other policy recommendations will provide long-term results.

9.1 Main Insights

The main insight gained from this research is that primarily there is a large disconnect between knowledge on the German federal government policy and expectations pertaining to I4.0. The experts interviewed and the participating companies possessed the technical knowledge of I4.0, but many were unaware of government policy developed on I4.0. This has indicated a large challenge for the German federal government to make their policy widely known, particularly within the M&E industry. Although the case study has indicated that there are enterprises that have exceeded government expectations within specific dimensions of SIMMI 4.0, without direct knowledge of federal policy surrounding I4.0, there can be benefits in great communication and cooperation to share this information. In order to achieve greater adoption, the federal government needs to participate with enterprises actively and make the policy expectations known widespread.

The first research question of this paper sought to determine what are the current guiding policy objectives and main outcomes which the federal government seeks to attain in German SME M&Es. This was determined through the conduction of policy analysis of previous federal policy on the matter of I4.0 and can be summarized in Table

10, which outline the aimed objectives of the federal policy pertaining to the IT and application landscape. The results of the policy analysis enabled the possibility to conclude that the federal government seeks to have enterprises within the stages of integrating I4.0 IT and application landscapes. The desired progression of the state within this matter is that I4.0 adoption has been expected to have already occurred and to commence upon the next level of implementing the fundamentals of interoperability, autonomy, and sustainability.

The second research question determined that in relation to a level of maturity, that I4.0 has been integrated into the IT and application landscape of German M&E SMEs, but fails to meet the government expectations, as there was an overall maturity level gap. The maturity analysis concluded that the case studies performed at par or below par the average level of SMEs and that the government expectations exceeded the average level by one level. The results from this analysis indicated that there was an inconsistency between what is expect and what is the actual result. Therefore, these results provided indication into particular areas of focus for future policy development, such as the CTC and VI dimension, which require greater nitration between the two to access the most of I4.0 potential.

The results of the maturity analysis and expert interviews were combined within the policy recommendations section of this paper to provide suggestions on where federal policy should be adapted to support I4.0 transformation within the IT and application landscape. The greatest challenges can be summarized into the themes of education, vertical integration, autonomous data exchange, AI and augmented reality, approach, financing, the adoption of standardized application systems from larger providers, and greater involvement of the IT department. Additionally, future federal policy should consider reverting to supporting the greater application and IT integration and transformation. The case studies indicated significant limitations within the dimensional analysis, and many current enterprises are not prepared to commence upon subsequent transformation step.

Overall, the main findings of this research are that there is a greater need for M&E SMEs to focus on integrating their IT and application landscape throughout their enterprise and between themselves. The lack of a robust IT and application landscape prevents these enterprises from commencing upon greater I4.0 transformation and will continue to leave them vulnerable to foreign enterprises which implemented greater integration. In relation to these findings, it is also crucial to indicate that federal government expectations and support do not match the current on the ground situation that German SME M&Es face. Therefore, federal policy needs to account for the current

as-is situation of SMEs and develop policy that supports the situation rather than publish policy which expects the greatest form of adoption when there is a current lack in supporting IT and application landscapes to support set desires for attainment.

9.2 Future Research and Recommendations

There are still many unanswered questions on how to address I4.0 adoption within German SMEs, and future research should still continue to focus on supporting the digital transformation of this sector of the economy due to its prevalence in different industry sectors and its economic weight. Therefore, there are a list of possible areas of focus for future researchers to consider in order to continue research within the field of the IT and application landscape.

Future research should continue to investigate the IT and Application landscape of SMEs in Germany and focus on researching different industry and manufacturing sectors. This would build upon the research to determine overall challenges and successes within this field, thus providing a cross-industry analysis of challenges within the adoption and transformation process to support the whole German I4.0 policy. The results of selected research could then be utilized to perform a gap analysis to determine if the results are being experienced within both industries.

Additionally, the research could be built off the preliminary information identified within this paper to continue to identify the impact of the IT and application landscape on enterprises' business processes and operations. Thus, providing a greater understanding of the role in which they contribute within the entire functionality of enterprises. Research into the field of augmented reality would provide significant benefits to academia and the private sector regarding its role in manufacturing and servicing machines. The investigation of the challenges and successes in integrating augmented reality technology with the IT and application landscape of the M&E sector would serve to support German federal policy objectives and the digital transformation of M&E enterprises.

The policy recommendation of a co-developed application module with a third-party supplier should be investigated due to its prevalence in the expert discussions and the results of this dissertation. Identifying how to incorporate the objectives identified for the IT and application landscape of the 2030 vision into the product can be investigated to determine what the product would entail and a financial cost for the development of such a product.

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11 Appendix

A Interview Schedule and Questions

DD.MM.YYYY, Respondent #, Position, Duration, Mean of Interview Conduction

02.03.2021, Respondent 1, Managing Partner, Duration: 33m 38s, over Zoom call.

09.04.2021, Respondent 2 Consultant, Duration: 34m 14s over Zoom call.

05.06.2021, Respondent 3 Executive Assistant, Duration: 20:00 over LinkedIn.

25.07.2021, Respondent 4 Former Managing Director, Duration: 22m 17s over WhatsApp audio.

06.07.2021, Respondent 5 Managing Partner, Duration: 54m 22s, over Microsoft Teams.

09.06.2021, Respondent 6 Head of Press, Duration: 33m 52s over Zoom call.

24.06.2021, Respondent 7 Professor and Lead Semantic Modelling & Applications Architect Partner, Duration: 1 hr 24m over Zoom call.

Research Question which the Interview Question Belongs to	**Interview Question #**	**Question Asked During Interview**
Research Question 1	1.	What are the guiding policies which the federal government in Germany have published to direct the digital transformation of Industry 4.0? What have these policies sought to achieve, particularly in the tool machine manufacturing sector?
	2.	Are there additionally Bundesländer policies and aimed outcomes that differ from the federal government? If so, how do they differ in their aimed outcomes and method of implementation?
	3.	Do enterprises account for Federal government policies and aimed outcomes when implementing I4.0 adoption? Why or why not?
	4.	Can policymakers help support I4.0 adoption, and if so, what can additionally be done to encourage greater adoption?
	5.	In your opinion, why did the German federal government adopt an approach which consisted of

		connecting manufactures/producers, SMEs and policymakers in the aims of promoting dialogue between stakeholders, as compared to other counties which possess a diverse target audience and approach?
Research Question 2	6.	What are some challenges that companies face regarding the implementation of I4.0, particularly in relation to government expectations?
	7.	How would you suggest that policymakers could adapt the policy to account for these challenges?
	8.	What are some successes in I4.0 adoption, which can be seen widespread in Germany? Particularly in SMEs?
	9.	How do you assess the integration of IT departments with I4.0 in German SMEs?
	10.	Does collecting data on how customers utilise products and how the data is utilised to improve the product commonly practised in SMEs?
	11.	How does the organisational/ strategical aspect (vertical integration) influence I4.0 transformation?
	12.	Is there a value in enterprise systems that support departments? If so, what, and should it play a more crucial role in I4.0 policy?
	13.	In your opinion, what level would you say most SMEs are on in Germany? Is the level you indicated the same regarding what level you believe that the federal government would want most companies to be on? (Based on SIMMI 4.0) a. Stage 1–Basic digitisation level: The company has not addressed Industry 4.0. Requirements are not or only partially met. b. Stage 2–Cross-departmental digitisation: The company is actively engaged with Industry 4.0 topics. Digitisation is implemented across departments; first, Industry 4.0 requirements are implemented in the company. c. Stage 3–Horizontal and vertical digitisation: The company is horizontally and vertically digitised. Requirements of Industry 4.0 have been implemented within the company, and information

		flows have been automated. d. Stage 4–Full digitisation: The company is completely digitised even beyond corporate borders and integrated into value networks. Industry 4.0 approaches are actively followed and anchored within the corporate strategy. e. Stage 5–Optimised full digitisation: The company is a showcase for Industry 4.0 activities. It collaborates strongly with its business partners and therefore optimises its value networks.
	14.	The utilisation of service-oriented cloud applications and big data applications can provide companies with a competitive advantage. However, privacy and data security is a major concern for the German federal government. What is your position on the matter of digital privacy, and how can SMEs continue with the adoption of I4.0 while attaining the position which the federal government wants for data security? Is this currently a challenge for many SMEs?
Research Question 3	15.	What are your perceived benefits of the current policy surrounding I4.0 in Germany?
	16.	What are the KPI's in evaluating I4.0 adoption?
	17.	Can the current policy be improved, and if so, how?
	18.	In relation to question 13, "In your opinion, what level would you say most SMEs are on in Germany? Is the level which you indicated the same in regard to what level you believe that the federal government would want most companies to be on?" What would need to be done from a policy perspective to achieve the level which the government sought to have attained if it has not already been done so?
	19.	Do you have any more suggestions or inputs on how the government can support I4.0 advancement in Germany?
	20.	In your opinion, what would be identified as the needs, expectations and issues with I4.0 adoption in Germany, particularly in the machine tool manufacturing sector?

B Coded Results of Expert Interviews

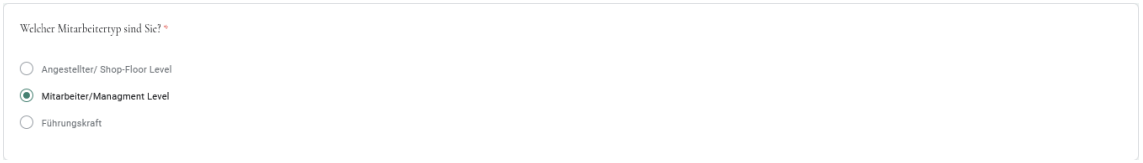
Yes: Coded as 1

No: Coded as 0

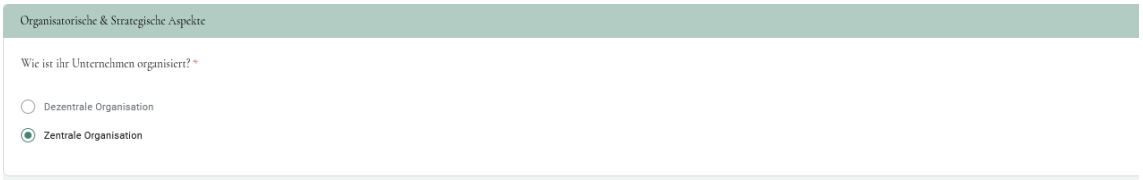
Partly: Coded as 0.5

Success and Challenges Identified	Respondent							Results
	One	Two	Three	Four	Five	Six	Seven	
Identify Federal Policy	1	1	1	1	0	1	1	Yes: 6 No:1
Identify Bundesländer Policy	1	0	0	0	0	1	0	Yes: 2 No: 5
Identify Policy Objectives Specifically	0	1	1	0	0	0	0	Yes: 2 No: 5
Interoperability a challenge	1	1	1	1	1	1	1	Yes: 7 No: 0
Standardization a challenge	1	1	1	1	1	1	1	Yes: 7 No: 0
Data Security/ Privacy a concern	1	0	0	0.5	0	0	1	Yes: 2 No: 4 Partly: 1
Reshape role of IT department	1	1	0	1	1	0	1	Yes: 5 No: 2
Isolated data silos/ application systems	1	1	1	1	1	0	1	Yes: 6 No: 1
Skilled workforce/ education	1	1	1	0	1	1	1	Yes: 6 No: 1
Policy as the driver of I4.0 adoption	0.5	0	0	0	0	0.5	0	Yes: 0 No: 5 Partly: 2
KPI as driver of adoption	1	1	0	1	1	0	1	Yes: 5 No:2
Finance as the driver of I4.0 adoption	1	1	1	1	1	1	1	Yes:7 No:0
Influence as the driver of I4.0 adoption	1	1	1	0	0	0	1	Yes:4 No: 3
Greater need for funding	1	0.5	1	1	0	1	0	Yes:4 No: 2 Partly: 1
Average level of German SMEs	Level 2	Level 2 to 3	Level 2 to 3	Level 2 to 3	NA	NA	Level 2 to 3	Average: 4.2 Rounded: 4
Level of Government aimed attainment	Level 3	Level 5	Level 5	Level 4	NA	NA	Level 4	Average: 2.5 Rounded: 3

C Survey Results M&E Manufacture A


Welcher Mitarbeitertyp sind Sie? *

- Angestellter/ Shop-Floor Level
- Mitarbeiter/Managment Level
- Führungskraft


Organisatorische & Strategische Aspekte

Wie ist ihr Unternehmen organisiert? *

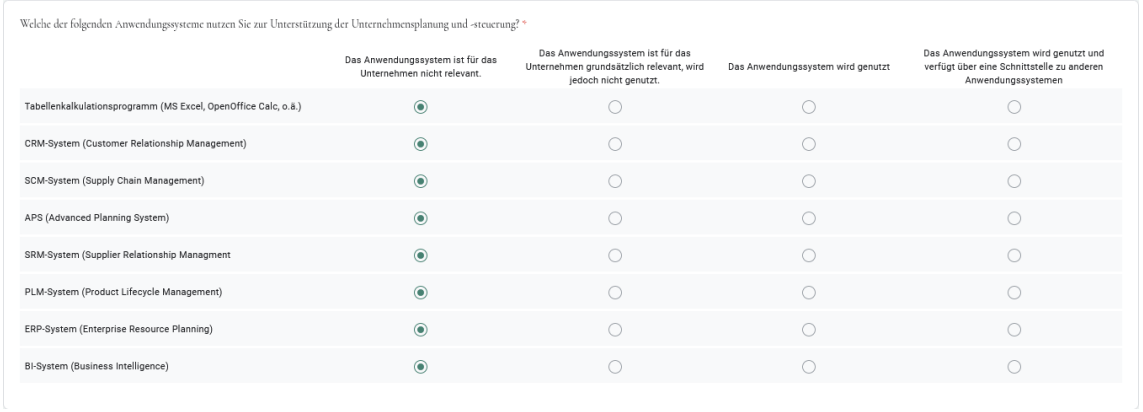
- Dezentrale Organisation
- Zentrale Organisation


Auf welcher Planungsebene erfolgt Ihre Unternehmensplanung? *

- Operative Planung: Kurzfristige Planung, i.d.R. weniger als 1 Jahr. Umfasst eine detaillierte Planung über "das Tagesgeschäft"
- Taktische Planung: Mittelfristige Planung i.d.R. 1 - 3 Jahre. Umfasst einen großen Teil der betrieblichen Aktivitäten
- Strategische Planung: Langfristige Planung i.d.R. über 3 Jahre hinaus. Umfasst die Entwicklung einer Unternehmensstrategie zur Erreichung der Unternehmensziele.


Wie erfolgt die Planung in Ihrem Unternehmen? *

- [ ] Die Planung erfolgt durch einzelne Personen. (z.B. Geschäftsführung, Produktionsleitung, o.ä.)
- [ ] Die Planung erfolgt durch ein abteilungsübergreifendes Team.
- [x] Die Unternehmensplanung wird durch eine interne Controlling-Abteilung unterstützt
- [ ] Die unterstützende Controlling-Abteilung nutzt unternehmensübergreifende Informationen zur Planung.
- [ ] Die Unternehmensplanung wird mit anderen Unternehmen im Wertschöpfungsnetzwerk abgestimmt und optimiert.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Anwendungssysteme

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Finanz/Rechnungswesen	○	○	○	○	◉	○
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IT	○	○	○	○	◉	○

Wie schätzen Sie die Integration Ihrer IT-Abteilung ein? *

- ☐ Das Unternehmen besitzt keine IT-Abteilung.
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- ☑ Das Unternehmen besitzt eine zentrale IT-Abteilung.
- ☐ Das Unternehmen besitzt einzelne IT-Abteilungen für die einzelnen Bereiche. (z.B. Forschung & Entwicklung, Produktion, Einkauf, Vertrieb und Rechnungswesen)
- ☐ Das Unternehmen besitzt eine zentrale IT-Abteilung mit IT-Experten in den einzelnen Abteilungen

Digitale Produktentstehung

Wie schätzen Sie die digitale Unterstützung der Produktion bzw. Leistungserstellung in Ihrem Unternehmen ein? *

- ☐ Maschinen und Anlagen sind nicht über die IT ansteuerbar
- ☑ Maschinen und Anlagen sind teilweise über die IT ansteuerbar
- ☑ M2M-Kommunikation ist teilweise umgesetzt.
- ☐ Maschinen- und/oder Prozessdaten werden teilweise erfasst.
- ☑ Es ist möglich ein digitales Abbild der Fabrik/des Unternehmens zu erstellen, alle Maschinen- und/oder Prozessdaten werden erfasst.
- ☑ Maschinen- und/oder Prozessdaten werden mit Zulieferern und Abnehmern geteilt.
- ☑ Die Produktentstehung/Leistungserstellung lässt sich vollständig digital als Ende-zu-Ende Lösung abbilden.

Werden Daten über die Art und Weise wie Kunden die Produkte bzw. Leistungen nutzen erhoben? *

- ○ Nein.
- ○ Ja, wir erheben anonyme Daten in der Nutzungsphase.
- ○ Ja, wir erheben personifizierte Daten in der Nutzungsphase.
- ◉ Ja, wir bieten die Möglichkeit an, uns mit den Kunden zu vernetzen.

Werden die erhobenen Daten genutzt, um Produkte bzw. Leistungen zu verbessern? *

- ○ Nein.
- ◉ Ja, wir nutzen die Daten zur Produktverbesserung.
- ○ Ja, wir nutzen die Daten zur Produktverbesserung und teilen diese im Wertschöpfungsnetzwerk.

Querschnittstechnologien

Nutzt Ihr Unternehmen (service-orientierte) Cloud-Anwendungen? *

- ○ Nein, dies ist für unser Unternehmen nicht notwendig.
- ○ Nein, aber es gibt Pläne in Zukunft Cloud-Lösungen einzuführen.
- ◉ Ja, teilweise.
- ○ Ja, in allen relevanten Bereichen.
- ○ Ja, service-orientierte cloudbasierte Plattformen werden gemeinsam im Wertschöpfungsnetzwerk genutzt.

Beschäftigen Sie sich mit der Nutzung von Big-Data-Lösungen in Ihrem Unternehmen? *

- ○ Nein, Big Data spielt für unser Unternehmen keine Rolle.
- ○ Ja, eine Big-Data-Lösung ist in der Planung. Erste Erfahrungen wurden bereits mit Big Data gemacht.
- ◉ Das Unternehmen nutzt eine Big-Data-Lösung.
- ○ Das Unternehmen nutzt eine Big-Data-Lösung und verwendet die Erkenntnisse zur Optimierung der Produkte und der Produktion.
- ○ Das Unternehmen nutzt Big-Data-Lösungen und die Erkenntnisse werden im gesamten Wertschöpfungsnetzwerk geteilt und genutzt.

Wie schätzen Sie Ihr Unternehmen im Hinblick auf Datenschutz und Datensicherheit ein? *

	Für das Unternehmen nicht relevant	Eine Lösung ist geplant	Eine Lösung befindet sich in der Umsetzung	Eine Lösung ist bereits implementiert
Sicherung der internen Daten	○	○	○	◉
Sicherung der Daten in einer Cloud-Lösung	○	○	○	◉
Das Unternehmen nutzt Modelle um die IT-Sicherheit zu optimieren	○	○	○	◉
Innerbetrieblicher Datenaustausch erfolgt verschlüsselt	○	○	○	◉
Kommunikation mit Partnerunternehmen erfolgt verschlüsselt	○	○	○	◉
Das Unternehmen hat einen Datenschutz-Beauftragten	○	○	○	◉
Die IT-Abteilung ermöglicht Sicherheitslücken schnellstmöglich zu schließen	○	○	○	◉

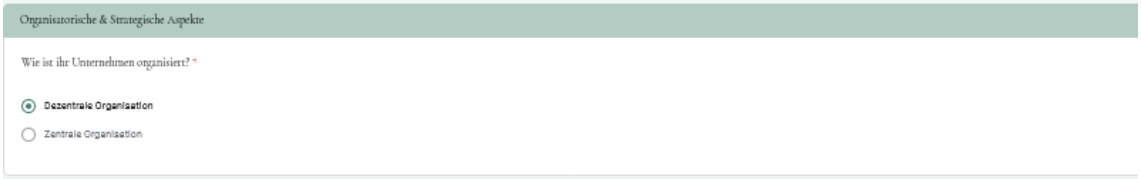
Welchen Reifegrad würden Sie Ihrem Unternehmen gemäß dem obigen Bild zuweisen? *

- ◉ Reifegrad 1
- ○ Reifegrad 2
- ○ Reifegrad 3
- ○ Reifegrad 4
- ○ Reifegrad 5

D Survey Results M&E Manufacture B


Welcher Mitarbeitertyp sind Sie? *

- Angestellter/ Shop-Floor Level
- **Mitarbeiter/Managment Level**
- Führungskraft


Organisatorische & Strategische Aspekte

Wie ist ihr Unternehmen organisiert? *

- **Dezentrale Organisation**
- Zentrale Organisation


Auf welcher Planungsebene erfolgt Ihre Unternehmensplanung? *

- Operative Planung: Kurzfristige Planung, i.d.R. weniger als 1 Jahr. Umfasst eine detaillierte Planung über "das Tagesgeschäft"
- Taktische Planung: Mittelfristige Planung i.d.R. 1 - 3 Jahre. Umfasst einen großen Teil der betrieblichen Aktivitäten
- **Strategische Planung: Langfristige Planung i.d.R. über 3 Jahre hinaus. Umfasst die Entwicklung einer Unternehmensstrategie zur Erreichung der Unternehmensziele.**


Wie erfolgt die Planung in Ihrem Unternehmen? *

- [x] **Die Planung erfolgt durch einzelne Personen. (z.B. Geschäftsführung, Produktionsleitung, o.ä.)**
- [x] **Die Planung erfolgt durch ein abteilungsübergreifendes Team.**
- [x] **Die Unternehmensplanung wird durch eine interne Controlling-Abteilung unterstützt**
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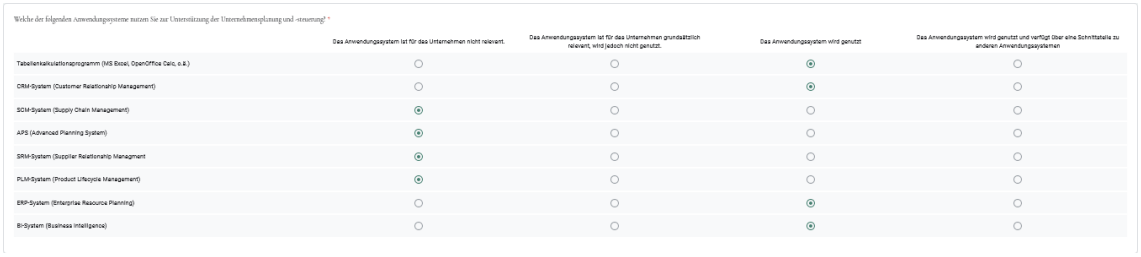
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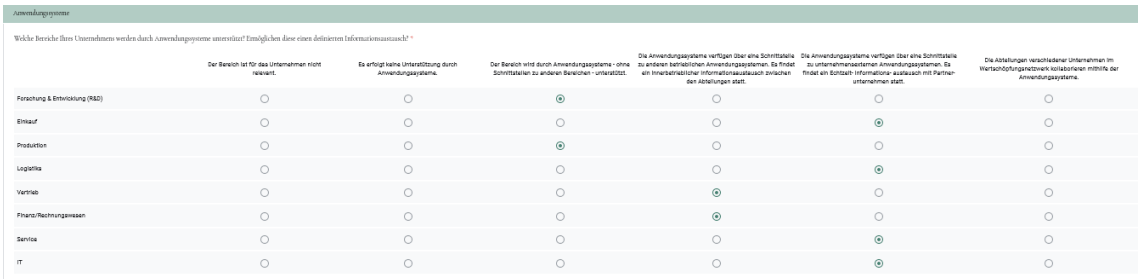
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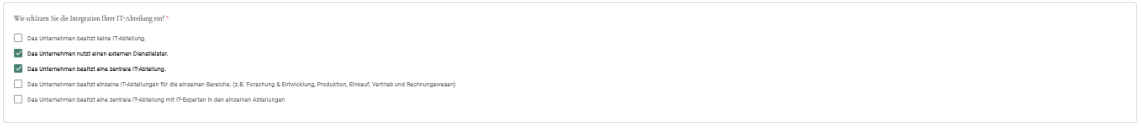
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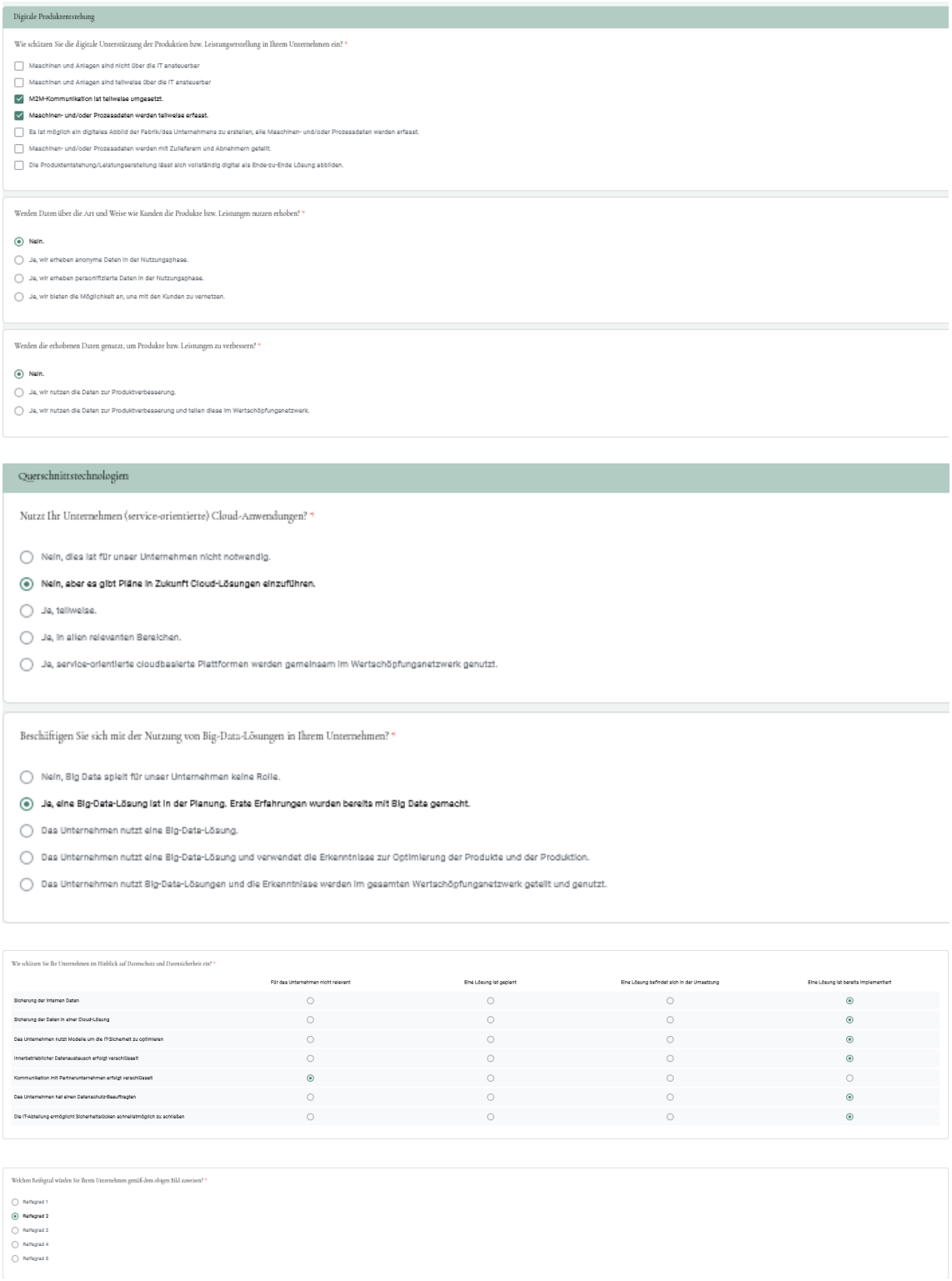

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Sicherung der Daten in einer Cloud-Lösung	( )	( )	( )	(•)
Das Unternehmen nutzt Modelle um die IT-Sicherheit zu optimieren	( )	( )	( )	(•)
Innerbetrieblicher Datenaustausch erfolgt verschlüsselt	( )	( )	( )	(•)
Kommunikation mit Partnerunternehmen erfolgt verschlüsselt	(•)	( )	( )	( )
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- ( ) Reifegrad 1
- (•) Reifegrad 2
- ( ) Reifegrad 3
- ( ) Reifegrad 4
- ( ) Reifegrad 5

E Respondent 1

Respondent 1

Ok, starting with the first question. I have a lot of questions for you. What is meant with government expectations? So as part of the first question, can you liberate a little bit on that.

Interviewer

So, what are some challenges that companies face regarding implementation of Industry 4.0, so particularly in the relation to what the government expects. So what are some challenges that companies experience, but also what are these challenges, especially in relation to government expectations? So sometimes there are challenges that companies may face that the government hasn't even considered. So I was wondering if there are some parts where companies are struggling and that the government hasn't even looked into yet?

Respondent 1

Ok, Yeah, I got it. Well, the thing I think I see for the first progress, is usually companies start struggling when they have to make an investment decision where the outcome of the of the investment is not clear. So, to give an example, whenever you can do a business case with a new investment and it comes down to the classical key performance indicators like decreasing cost, increasing quality or performance it's basically simple. And the question they ask is, OK, what is the return on investment one year, two years, three years, whatever. And I think that coming through to the stages you were mentioning in one of the last questions I think for the first stage is this answer is quite easy to give here, because you can do this business as you can sort of explain what the benefits of digitization are in terms of what it brings to me when I process. Of course, it gets a little bit tougher when you're talking about data analytics, because then you have a lot of upfront investment in people, technology, resources, whatever, and believe this happens at a time where the high-cost hypothesis are not clear. So meaning you are investing into something like data analytics and you don't really know upfront what you are going to do with it. And so, this is what I see when talking to companies right now, what one of the challenges is in especially in reaching the later stages. And I'm not really sure if the government can or has something or in their toolbox for that, and how they can help companies with that.

Respondent 1

So they, of course, are showcasing a lot of things in Germany. And we have different initiatives. We have the industry for LEPs and other initiatives where you can sort of say, oh, go and check out those things. But when it comes to implementing that in the old firms, people are struggling. And the reason is that probably already coming through to the second question. Well, yeah, how can you solve that? It's not easy because as the owner of the company, you need to be willing to make these investments here. Then you need to have the budget. If you don't have the budget, then it can become difficult because probably you won't get

the budget from a bank or from a classical bank. And that's, of course, is the point where the government could step in. We have a firm, I think, one of the largest development banks in the world within Germany, or so setting up a program, a program where you can funding. They're financing from them with very low interest rates, much like we do in the Corona pandemic, but now that could be, of course, very interesting. Yeah, so because that's how they handle it today. So if you if you're short on money as a company and you need a credit, you get it from them and they will fully cover the risk of not getting the money back. So let's say the same could be done with high risk investments into the industry for the new technologies.

Interviewer

Ok, so you would say that the majority of the challenges, or at least the main challenge, would be access to funding? For investment.

Respondent 1

Yeah, and access to funding is the point, which is especially difficult for SMEs. For corporations, of course, this is a completely different ballgame, you know.

Interviewer

Ok, are there any other maybe not as pressing or challenges that companies might face besides funding or would you say just primarily be funding?

Respondent 1

Yes, there could be I mean, access to talent is, of course, a question. when you look at especially new jobs, like a data scientist, those people are not available everywhere. Of course, you get them. You can hire them when you're working close to Köln, or if you're based in Hamburg or whatsoever. But when you are somewhere on the countryside, of course, it's tough to get the right people. And when we look at some in the manufacturing industry, a lot of them are somewhere in more or less remote locations. So talent is another topic for sure.

Interviewer

Ok, what are some successes in Industry 4.0 adoption, what you can, which can be seen widespread in Germany?

Respondent 1

So after close to Ten years since we started discussing the topic, I'd say that everybody's heard about it, so there's no M.D or company that hasn't heard about industry 4.0. And I think really most of the companies started investigating the topic and started understanding what's in it for them, which is very good at the

same time. This helps a lot to bring the classical topics to the surface, like investments to IT. And we have often enough the situations that we have a lack of investment in the past. So a lot of things would have been possible, probably.

Respondent 1:

Yes, to what I said was that regarding that point. So having the awareness for industry 4.0, they went on television and I would say the government and also NGOs, made a lot of noise for the topic, which helped because most I would say 95 percent of manufacturing is in East Germany are dealing with the topic. So at least they are investing for investigating and checking whether this is a topic they could benefit from. And in the first place, is that I would say are two topics which probably could be addressed like 10 years ago. These topics are now on the surface, so they are visible to the board or to the management. It's much easier to get the budget for this freedom, but that's quite important because quite a lack of investments into classic highlighted topics, which is what I say is now solved and which is the key part to where you can build upon to truly take advantage of industry for new technologies. Apart from that, I think those technologies where you can Compute or can calculate an easy business case, and those things are now the question of, how can you scale them? So I think that that's a topic that you see you write about in. Germany is talking about software, when you look into Europe's software, and, yes, these are really some things that are strongly growing now for the last couple of years.

Interviewer:

So, actually, just adding onto that question, do you think that the government may have contributed to a lot of these successes, or is it more of NGOs, like you mentioned, and different organizations that have been promoting the spread of the topic, that are promoting the discussion?

Respondent 1:

Yeah, I would. You know, I would say it's probably a mixture. So they are NGOs who were addressing the topics for sure. But there are of course, research activities that are funded by the government. So over the past years, with the help of the government, they made significant investments into research programs. And they also helped with different initiatives to raise awareness for the topic. So there I mean, that's probably the downside of a federal system. But in each of the Regions, we have different programs there, but I would assume there's not a single region without one or even multiple initiatives which have been launched by the government.

Interviewer:

That it's ok. All right, so moving on to the fourth question, how do you assess the integration of I.T. departments with Industry 4.0 in German SME?

Respondent 1:

It's a good question. So as we perceive it, the I.T. departments are still treated as a classical office, I.T. departments, meaning they are taking care of all the processes taking place in the offices, but they are not so much involved when it comes to processes more on the manufacturing level. So. What we see here is that we this is usually more in the hands of the production, IT so people who in the past worked on automation topics, they are now in charge of industry or at least for those technologies that are close to the shop floor. When we are talking about aspects like I think you call it enterprise systems or business software like ERP or CRMs, then this is probably in the hands of the security department. But at some point, of course, you need to have an interface between the office I.T. department and the production company. And one aspect that we see very strongly is that experts outside the I.T. are strongly looking into industry for that or technology. So often enough, these initiatives are not launched by the department they are launched by the operations manager or someone else from the business.

Interviewer:

yeah, so it's there's definitely a lot to move forward with in further integration, right? You would definitely say that.

Respondent 1:

Yeah, there's a lot to move forward with further integration. I think you have to redefine the role of the classical. I mean, there's the idea of greater democratization, where you provide data to all the stakeholders and they can run analytics on their own, and the question is, of course, what does it take on roles and responsibilities? And how can you make sure that it does not turn into a bottleneck?

Interviewer

For the fifth question, does a collection of data on how customers utilize products and how the data is utilized to improve the product commonly practiced in SMEs?

Respondent 1

I wouldn't say it's commonly printed. I would say it is a practiced when it's possible. When you as a person are producing a physical product that can be digitized so it can be turned into a cyber physical product, then I would say SMEs are investigating is that something for them? There are two challenging aspect, from my side. First of all in the B2B business, when you have a cyber physical system or a physical product in place, you need to convince your customer to use it. And the question is always, what? What's in for the customer? So why should he allow you to send data back to your company to do something with it? So this whole field of smart services is something which is yet to come first. So there are prototypes, but that's probably something which we'll see more in the next couple of years. And then the second aspect is that is said, we

are often enough with the same ease we are in the B2B business. And so could be the case that you are not producing a product that can be smart or you are producing components for example, parts that go into a machine or that go into a car. And you have the idea of the producer of components, but you're not the OEM itself. So the question is, how do you get access to the final customer who is willing to pay for a smart service or who's willing to use data which is coming from the from the product? So that's a bit challenging.

Interviewer:

Yeah. That definitely is, that's actually quite interesting that you bring that point up I haven't read any of that yet, but that does seem like it would be a large challenge moving forward. OK, so then I would say for the sixth question, how does the organizational and strategic aspects of vertical integration influence Industry 4.0 transformation?

Respondent 1:

That's a very important point. So if you want to rule out Industry 4.0 on large scale, it is definitely an organizational or strategic problem, call it a transformation. What coming to the strategic aspects before launching in an industry for initiatives in to quite clear on where you want to end up. So what will your business model and the future look like? Which, of course, could be a different business model. But what are the business models as you're going to run the company in the future of that? That is quite important to make the right choice. And from an organizational perspective, I mean, the things we see with industry 4.0, if you play it the right way, is that it will change a lot of processes and that it also will change the way of working. And from this, I expect it has of course, a lot of strong organizational aspects. So it's not only about technology, but you need to embrace the people and the organization and going for an industry transformation.

Interviewer:

You know because Industry 4.0 is disruptive to the common practice, to all the traditional methods, so you have to re-evaluate almost every aspect within a company to see how it can provide value.

Respondent 1:

Right now, at least the way we see it.

Interviewer:

Yeah, not everybody sees it this way, but OK, for the seventh question, is there a value in enterprise systems that support departments? And if so, what? And should it play more of a crucial role in Industry 4.0 policy

Respondent 1:

you mean, for example, the business software like in your piece?

Interviewer:

Yeah, exactly. Like an ERP.

Respondent 1

Yeah. OK. I mean that's of course it helps to link departments together. The strong focus of industry should be on the interfaces between different departments. And so in the sense that you streamline business processes throughout the entire firm. So enterprise systems like your PC or any assistance which are reflecting the business processes of play, of course, the crucial role you.

Interviewer:

So you believe that ERP systems play a really important role in supporting Industry 4.0 adoption and transformation?

Respondent 1

Yeah, I do think so. At the same time, adaptions to the enterprise systems are usually quite costly. So and in that sense, the enterprise system should at least be present, as in the backcountry, also reflecting all the processes. But of course you can work with more lightweight solutions on the front end. So on different parts, so you need to have a good mix between enterprise systems and other software, you are using this, for example, the concept of the idea of two speeds. So the rock solid system, which could be the enterprise system and then other software, for example, like. Frontend and software, which comes more in an EP style where you can update frequently, so I think we need to reshape the I.T. infrastructure as a whole, but definitely should keep the system at the heart of the systems.

Interviewer:

Ok, so then moving on to the eighth question I had, which was about the different stages. So in your opinion, what level would you say that most SMEs are on in Germany? Is the level you indicated the same regarding what level you believe that the federal government would want most companies to be on? It's based on SIMMI 4.0.

Respondent 1:

So nowadays, I would say most companies are on level one to stage two. So at least the majority of them are some stage and some of them looking at stage three and the upper stages, but the majority will be on stage two I believe.

Interviewer:

Ok, and what stage would you think that the federal government would want most companies to be, have or have achieved already?

Respondent 1:

I mean, in the end, it's a question or it's the question of the trade off between what is in the businesses, what is the technology level and from a government perspective. I would say at least stage three is something they should see as the final level for companies because until stage three, it is quite easy to find value.

Interviewer:

Ok. So you believe that stage three is like the level where you kind of where most companies can see and look forward to see that there's value in the further adoption, that's a stage four and five. It would cost a lot of extra funds and resources and time that the company doesn't necessarily have a lot in SMEs.

Respondent 1:

Exactly. And stage four and five for the business model itself plays a major role. So the business model really, if the direction if it makes sense to on stage four or five.

Interviewer:

Ok, yeah, and for the last question the utilization of service-oriented cloud applications and big data applications can provide companies with a competitive advantage. However, privacy and data security is a major concern for the German federal government. What is your position on the matter of digital privacy? And how can SMEs continue with the adoption of Industry 4.0 while obtaining the position which the federal government wants for data security? Is there currently a challenge for many SMEs?

Respondent 1

So first of all, I don't think data privacy is really a challenge for most of the SMES, and when they state that privacy is a is a major challenge, then that is really a made up challenge because the use cases I see in industry can be realised perfectly fine without a brave breaking any privacy rules at some point. There's, of course, the question of what the workers council say is accessibility. Also, you need to invite them to your plans or to the project in a very early stage. But when you discuss this and usually privacy is not a problem as I see it, and you have probably same for the cloud applications. I mean, there are a lot of SMEs who are sort of say reluctant to work with US providers like Microsoft or Amazon Web Services or whatever. And again, for me, this is a little bit of made up. And when you look at corporate. All corporate, I know, with the Microsoft cloud over the Amazon, say this is not a big deal for me, on the other hand. The question, which I think is much more interesting is. How do we sort of say keep the interface to the customer and how do we. What does creating value in real data economy look like so I'm talking about the move to two

platform ecosystems here, which is perfectly understood in the US and or in China. And there we are struggling with that quite a lot because course, we have no clue yet how that might look for our industry driven economy. And there the government started a couple of initiatives like the International Data Space, which I think are quite interesting to look into. And we need to be, yeah, starting to create a vision on how our future value creation will look. So this is for me, quite a good example, probably a bit late for five to 10 years late. Nevertheless, we started working on it.

Interviewer:

Yeah, that's important. You said that most companies were on stage 2 moving towards stage three previously. Also mentioned that one of the big restrictions for Industry 4.0 is access to funding and talent. Would you say that those are pretty much the same things that are holding back many companies from reaching stage two to stage three? Would they be the same challenges?

Respondent 1

Yeah, I think so.

Interviewer

Ok, and also maybe from your experience with working with many different SMEs with Industry 4.0 adoption, do you know if many companies consider policy from the government or is it kind of a point where it's just really neglected, nobody really focuses or knows anything about it? Or is there different state like policies?

Respondent 1:

tough questions. So what I see most companies are to take care of its self, that the eco system or the environment, they are working. And so making sure that taxes are affordable, that the way how you can sort of say. Employ people and what the regulations are there, so I think these aspects in the end play a more crucial role for the companies than direct industry, for the policies given by the government. OK, I don't know if that's clear.

Interviewer:

Yeah, , so you're saying that the majority of it is the macro environment, so. Yeah, so like the infrastructure access, the Internet, the taxes. Exactly. Yeah. These are the more. Yeah. OK.

Respondent 1

And these are the things we definitely need to solve. So infrastructure is really.

Interviewer:

And, you know, so I guess my last question is, do you have any suggestions or inputs on how any additional ones on how the government can support Industry 4.0 adoption or pretty much everything that you have said?

Respondent 1

Yeah, not in the sense that I can point this down on their list, down to a specific program or so, what I think is important is that policy makers really understand the topic and that you as a company or as an individual, they believe that they know how the future economy will look like. It's working, so we need some fresh minded people there who have a clue on what digitalization really means. So, yeah, but that's not something that you can do right now in the governmental program.

F Respondent 2

Interviewer

Okay. So the first question is, what are the guiding policies which the federal government in Germany have published to direct the digital transformation of industry 4.0? What have these policies sought to achieve, particularly in the machine tool manufacturing sector?

Respondent 2

Yeah, that's kind of an interesting question. I read through the guidelines. This morning, again, there's these industry guidelines published by German government, and France, some interesting parts in there, for example, there is a phrase that states the time factor size when implemented industry 4.0 solutions and when I researched it in 2016, I had this phrase somewhere. And now five years later, it's still in there. And a lot of our customers are still beginning with the transformation. And time can't really be that crucial of a factor. If it's five years going by, and there is not much change. So yeah, that's a bit interesting there, I think. And also, some other parts are quite interesting, the state of the industry for but all itself does not represent any value. I would really disagree with that. Because if it's like that, if the data you gain from industry, 4.0 has no value, then you could share it public on the internet, and everybody could see it. But none of the companies I've worked for, would be willing to share their production data publicly. So there must be some value behind it. And in fact, there are these are some phrases I found in there, which I think the person who wrote it, maybe has no real idea. And then the guidelines themselves. Yeah, I think they read a bit. Not so clear what they want to achieve. We'll say it that way. So when I read through them, I was like you. Okay, great. And what should I do now? How old is my company? So maybe you had some more insights in the guidelines than I do? But that's what I found out.

Interviewer

Okay, yeah, that's interesting. That's one thing that I'm looking at is what are the successes and challenges so that would definitely be a challenge is that with the with the timeframe, nothing, has happened within four or five years now.

Respondent 2

there's having a lot of things in the professional side that the data software gets better the more cloud technology and so on. And also the manufacturing tools, the machine tools itself, can have a lot of data, and they can collect them, and they can send whatever you want. But the company itself still doesn't use them. or most of them, don't use them.

Interviewer

that is something it's normally the bigger companies that are if, at all are being used. And they're just adding more types of sensors to gather the data I found.

Respondent 2

And speaking with them, and I'm not sure if we have the same industry guidance, but there's some toolbox in there with some, some different stuff where you can see if your company is ready or not, for the official guidelines, and there are a lot of parts in there, which I would not do in that way. But yeah, I mean, they are guidelines, but I'm not sure we're quite sure if these really achieve what they try to achieve with it.

Interviewer

Okay. And then for the second question, are there any additional Bundesländ policies that are aimed outcomes that differ from the federal government and if so, how do they differ the aimed outcomes and methods of implementation

Respondent 2

I'm not really sure if we have specific guidelines. I mean, they have a webpage, which states choose to take your industry 4.0 and it just keeps saying things like we want to be the key states in Germany for industry 4.0. And we do everything we can for key technologies and offers deterrents. But, yeah, sounds great. Do it. I'm not stopping them. But they're already guidelines. It's just a statement.

Interviewer

So it seems to be more with the federal states and Germany that there's more statements and lack of action. It's like, we want to be the market leader, we want to be the leader of the state. But how? I found, especially when you're looking at the definition of industry 4.0 it can, it can differ on what you're looking at. and there hasn't been a set criteria or guidelines for implementation, really, that have come out on how to achieve it

or implement what you want within the policies, and the government does seem to be kind of all over the place.

Respondent 2

I think it's also hard to mention, I mean, you can have a very small company like 10 guys working, doing specific stuff. And they don't need real industry 4.0, if they have these old machine tools where they drill by hand, it's fine. They can do their jobs, they're quite fast. They know what they're doing. It's okay for the company. There are also some large companies who honestly have no idea what they are doing. And they are happy that at the end there's a product coming out of the factory and it's still working. Yeah, that means great depends on what you're doing and what you're trying to manufacture. So that later next question where we can get in detail with the customer, for right now and what they are doing is okay.

Interviewer

Yeah, so then the third question is, is, do enterprises account for federal government policies and aimed outcomes when implementing industry 4.0 adoption? And why do you think they do? Or why do they not account for the government's perspective, or desires,

Respondent 2

that's also quite interesting. I never had a customer who said, we are doing this transformation, because our government wants us to do it. So it was more of the financial benefits, or we heard about it and moved on to the aesthetic and want to be the leader of our technology. But I never had a customer who said, hey, we hired you as our consulting company to help us achieve it, because our government wants it to do so.

Interviewer

That tends to be something different, as well, between Germany and China, you find a lot more companies in China, that the government has an influence on the industry 4.0 adoption there. And investment in the companies.

Respondent 2

That could also be in my opinion, because we are not that patriotic in Germany. So let's say China, the government's want to do something, they are maybe more willing to do it. Or even in America, if you have somebody like Trump saying we need to do something the companies do it, because he said it. And it's cool to have it on our website. We did it for our government in Germany, no one cares. So it's not like a marketing point or selling point for your company.

Interviewer

So the government really has less influence than in other countries. So for the fourth point, can policymakers help support industry 4.0 adoption? And if so what can additionally be done to encourage greater adoption?

Respondent 2

I think then there's a big part of the financial incentive or the financial benefits, if companies can, let's say, take the investment of their taxes or get a big tax return if they implement in a specific way. That would certainly I think, have more of an impact than just a paper stating, oh, we want to be the market leader

Interviewer

In your opinion, why did the German Federal Government adopt an approach which consisted of connecting manufacturers and producers, small, medium sized enterprises and policymakers in the aim of promoting a dialogue between stakeholders as compared to other countries which possess a diverse target audience and approach?

Respondent 2

That question, I honestly can't really answer I don't know.

Interviewer

then for the second question, or for the second research questions for the first one, it would be what are some challenges that companies face regarding the implementation of industry 4.0, particularly in relation to government expectations.

Respondent 2

That's exactly the point with the technologies out there, in my opinion, the government in the guiding policy has like a few points, you need to connect the manufacturer process, you need to make smart products. But what do they mean with that? What is the smart product, what is a smart factory, I can show you a picture of the let me share the screen, I will send you a data path a picture of the words where you can see the different technology behind that? And for Microsoft, for example, it like 1-234-567-8910 1112 13, around 15 different services, you need to implement a data 4.0 solution. And they're not even the product itself in there, it's just event up who would get the data from a product or from machinery, and then you would need to store it, you would need to act on it, you would need to have a machine learning tool, you would need to store them in the data warehouse, stuff like that, you will need the reporting tool in the end. And I know these tools for Microsoft, but they are the same for the Google Cloud. They're the same for the for the Amazon, EBS cloud, Oracle and something like that. Also, these are I guess, more than 200 different services. And you can't just simply know them as a company and know what to choose for your product. What would be the best approach? And I think nobody right now can do that. Okay, so this is the thing, a

real problem companies face even if they want to do it. They simply need somebody who helps them design the solution, especially if they're smaller, medium sized companies.

Interviewer

So would you say that would be a role that the federal government should take as an approach?

Respondent 2

I don’t think that the government could actually do it, but I think they need to account for it, they need somehow, maybe to help companies with some certificate what is good in German law, so which companies provide them? Because when you take something like the Google Cloud right now, you cannot be sure if the data policy is supported or not? Because there are still lawsuits going on. And we are not certain if they comply to the European rules. And the German words are not coolest as they do. But I mean, Google can say a lot of things.

Interviewer

Yeah. There's a difference between them. So I guess, for the second question is, how would you suggest that policymakers could adapt the policy to account for these challenges? And I think you've answered that already with types of tax breaks, decision making. Okay, so then the third one is, what are some of the successes that you've seen in industry 4.0 adoption, and which can be seen widespread in Germany, particularly in the SMEs?

Respondent 2

I only have one, but I have no idea if it's widespread in Germany, and I honestly can't really give a dedicated, real good answer to that question.

Interviewer

So then, how do you assess the integration of IT departments within industry 4.0 and Germans SMEs?

Respondent 2

When our company gets approached by the IT department, mostly to the IT department, they tend to have a good idea of what they want, because they have these internal departments, which are like their customers, and they tell them, hey, we need a new reporting software, we need to see this and that or we need to change our data warehouse. And then they come to us and asked us, okay, how can you help us so maybe they have a specific idea and say, okay, we need that technology implemented for us to get our data in there, get us a password and, that's it. That's quite interesting, because then the customer already knows what they want. But on the other hand, there are all sorts of customers who just say we want to go into Cloud. Yeah, which

one? I don't care. Okay, great. So, we really have them the technology and defining what their needs what they not only want, but what they really need, because that's not always the same.

Interviewer

there seems to be like maybe a lack of information or understanding on what can be used. They just kind of see all this, and say I hear that this makes a benefit and I just want to have a benefit from this, and it shows a lack of understanding of the systems and processes.

Respondent 2

that's, what I said in the answer to the first question. You have these, like 20 different technologies you need just to have this simple pipeline for industry, but also, if you now say, okay, I have a machine here it says it's IRA industry four, but already, it can divide pre the data in the cloud. So how do I do it? And then now you buy this one, you need to have a data hub, you need a data lake, you need a data warehouse in the middle of machine learning tool. And then things start to get really complicated. So if the idea is I want to have it, then we need to help them get there.

Interviewer

Yeah, they need direction. Yeah. Okay. Does the collection of data on how customers utilize products and how the data is utilized to improve the products commonly practiced in SMEs?

Respondent 2

Yea it is, but not much to add on that

Interviewer

How does the organizational and strategic aspects, so vertical integration influence industry 4.0 transformation?

Respondent 2

That's also a tricky one for me, because we have normally one customer in the whole supply chain, with just one company, we have them and we are don't see the impact for the whole vertical integration over the company's borders, within a company, there can be quite good results. And the organization is normally helping the transformation because normally the management has this idea. We want to have the industry 4.0 and the first thing they do is starting to change the organization in turn, but over the company, itself. So if you have a whole supply chain, I don't know.

Interviewer

Yeah, it's hard to see, I guess really how it all spreads out? If you're not really looking at it from a bird's eye view, more or less, right?

Respondent 2

Yes. And also, if you're looking from the bird's eye view, you can ask the top manager, hey, did you, do it? And he says, yes, of course. But if you then start to make a deep dive into technology, they're using cm industry 4.0. And there's an interest sitting there typing from the one system and the nervous system. Yeah, that's great integration. Good job. Yeah,

Interviewer

I find that there's, a lot of different systems where, people are copying information from one thing into an Excel sheet, and then taking it from the Excel sheet to put it back into something else.

Respondent 2

that's quite stupid, because an x is a CSV data. And you can just paste it, there is no need to handwrite it. That's one of the simplest tasks you can do.

Interviewer

in some places, there's really not any integration at all in their systems.

Respondent 2

And if you ask the manager, they're like, yeah, we have the best integration ever, we have systems working fluidly? Yes. Because there's an intern five days a week doing it for you. Yeah. Good job.

Interviewer

Is there any value in enterprise systems that support departments? And if so, what and should it play a more crucial role in industry 4.0 policy.

Respondent 2

That's something I could show you and some kind of reporting enterprise system, but maybe you can clarify the term enterprise system, to understand,

Interviewer

Like an ERP.

Respondent 2

ensure that they can help if they have the right, data and have the right KPIs. And then enterprise system can actually measure it, then, of course, but then they need to know first what they want to know. Maybe that's a bit of a problem.

Interviewer

And then this one's kind of actually, the eighth question was kind of based on where SIMMI comes into my research. So with what you worked on, in your opinion, what level would you say most SMEs are on in Germany? Is the level you indicated the same regarding what level you believe that the federal government would want most companies to be on? what's happening?

Respondent 2

I think most of the companies are between two and three. In my opinion, then I think more and three, maybe today. But what the government wants the companies to be? I'm not quite sure. I mean, sure they would want everybody to be in the highest level. But if it's the real expectation, I don't really know. And also, like I said, depending on the company, you don't need to have the highest industry 4.0 stepper. And if you are like small company like to compare Porsche, who's building special Porsche cars for customers, they are like 150 employees or something like that. They don't need to be industry forward already. They work together in their small company plant, and they produce great cars. But on the other hand, if this manufacturer is in the car supplier industry doing like some type of seatbelts or stuff like that, for big companies, they also want 100 employees, and they should be on a higher level, because that's what the customers, and the automobile industry really wants them to be. They want to know when the systems are there, and how many products will be delivered in which week? So where, I think most companies are on is three. But I think the government wants them to be on four or five, but I'm not sure.

Interviewer

And then for question nine, the utilization of service-oriented cloud applications and big data applications can provide companies with a competitive advantage. However, privacy and data security is a major concern for the German Federal Government. What is your position on the matter of digital privacy? And how can SMEs continue with the adoption of industry 4.0, while attempting to attain the position which the federal government wants for data security. would you say that this is a current challenge for many SMEs? So I think this kind of goes back with how you were talking about Google and their regulations. But yeah, what do you see on this?

Respondent 2

I'm in fact, a certified data privacy or data insurance benefactor in in Germany, so I can help work to adapt often for a company and have them comply to these rules. So I think I can go more in detail on that question. Because I know what I'm talking about. There, I think, the common misunderstanding of people with data

privacy in Germany. If you mentioned a system and say, What about industry? 4.0? What about new data warehouse? Then mostly, if somebody doesn't like the idea, he comes up with? Oh, what about data privacy? Great, what about it, and they think they don't understand what it's all about. It's about data from human beings, when you can then identify a human being itself. So their sex, their gender, their sexual orientation, stuff like that. And most industry 4.0 stuff does not have anything to do with the sexual orientation of the employees. Yeah, as far as I know, machines. And then the data security, on the other hand, okay, that's there's another part, but you have certified data security engineers all over the place, they can help you build keyboards, build security applications, with firewalls. And that's, I think is fine with data security. But data privacy as most times has nothing to do with what the company actually does. And even if a company has some special kind of data from their customers, they want to keep private, they can have them in a local database somewhere in a security compliance system here in Germany, and just use the analysis data of the customer number in the Big Data Warehouse. And that can be wherever they want, because it's now no more personal data. It's just the number. And then they are fine. So I see that there's a problem of the communication between the German government which adopted the new data privacy rules a few years ago, and not communicating what its all about. And I don't know if you read it, but they started to take the names of the houses and said, oh, we can't state the name of the people living in there on the front door, because that's data privacy. What? Sorry, but this is just stupid. Yeah. That's my big party, and also the uncertainty with the data regulations of the United States, what the state can look into. And on the other side, what we in Germany would like that they not look into our private data. And that's a bit of guesswork today. And the fights are a bit too high for guesswork. So there would need to be the need for clarity on what German companies can do and what not

Interviewer

Yeah, thank you that was actually really insightful. Okay. And then going to the interview questions for the third research question for the first one is, what are your perceived benefits of the current policies surrounding industry? 4.0? In Germany?

Respondent 2

I honestly have no idea. most parts of the question part three were not to mention. We have no idea what I could say.

Interviewer

Okay. So most of our research question three, you don't know anything?

Respondent 2

No, it's the current policy be improved. I mean, we talked about it more clarity and data privacy, maybe some more clarity in the guidance. That's question three, I think. And question you asked, but if the German

government can achieve what they want. And I'm not quite sure if the German government knows what they really want to achieve? So I mean, we have some people talking about digitalization, and they're here because they can write an email. That's great.

Interviewer

Yeah. And they like to say all the buzzwords like digitalization and blockchain and all those other types of things to make it Sound like there's something happening.

Respondent 2

Yeah, especially with some of the titles. But yeah, I also work in industry, data warehouse, and I started talking about data warehouse optimization software. I'm currently doing some research in and I start to see their eyes turned a bit, like turned inside. And you see, they can't really follow what I'm talking about. Just stop it right here. That's a good. Okay,

Interviewer

Do you have any more suggestions or inputs on how the government can support industry 4.0? I guess you've already answered those.

Respondent 2

Yeah, I mentioned this a few times, we've need better guidance, and maybe some help, in form of certifications, that not only universities have to do some research in and ask companies how their state is, and how they see themselves, basically what you're doing right now, more of a state approach so that it's a bit more efficient. Okay, and then you could actually have a picture of where the company is now and what do they want to achieve? Or maybe even have some guidelines on a smaller level or more granularity level? Because if you say every company needs to be in suite for better, great. As I said, the manufacturer who's making chairs does not really benefit from industry 4.0. So maybe some more details from the German government would be nice.

Interviewer

Okay. And I think you've already answered number six as well. Right with what would be identified as the needs and expectations the issue.

Respondent 2

the last question because the machine to manufacturing sector, they have pretty good data on what they are doing. Because, yeah, obviously, you have the working right now with the customer in a car manufacturer. And they have a production data warehouse, which really is industry 4.0, takes 1 day to build a car, they

can track in their data warehouse, every screw of the engine of the car, how much it was turned, how much force is used? When was it turned? They have measuring points all along the line. So which engineers in which car? How long does it engage? Which screw is maybe faulty, or what kind of screws is used? Which screw came from which factory plan from their smaller companies? And what is the noise level inside the car, and all the data is tracked multiple times a day, they have a huge data warehouse where all this data is tracked. They can tell you exactly if you come back three years later and asked, hey, my car's broken down, they can go into there and see if there's a factory plant. And let's say Bulgaria, they messed it up. So that screw broke. That's quite cool. That I don't think that every company is on that level. Now.

Interviewer

That's really cool that they that they've that sounds really fully implemented with everything.

Respondent 2

This is something I would say yeah, they are fully implemented. And I don't think they would do an interview with you that why I did not ask them because they are just right now in the development process and want to go into Cloud. This is all done locally on a local server. I would not even say they are on level five because they can see it in the internet. Yeah, if you're in the internet, but not in the in the global web. So even they just start to go in the cloud, so

Interviewer

yeah, so they're even though, that's really cool. I found some companies, like dmg has really pushed for industry 4.0 adoption. But that's one of the reasons why I focused on the machine tool manufacturing sectors, because there's been a lot bigger of a push there. And also, the machine tool sector, a lot of it is kind of at the heart of the German economy. So a lot of them create parts for other industries. So it's really, beneficial for them to have industry 4.0.

Respondent 2

And I think that's the industry, the German government is most concerned about. Talking about industry 4.0 they're not talking about the guy who's making wooden furniture now. I think they're more talking about the machine tool manufacturer in that, especially the automotive industry.

G Respondent 3

So on a general note regarding the German policy framework, I would say that the most important aspect would be the establishment of Plattform Industrie 4.0. A comprehensive and inclusive approach to join forces of industry, politics and academia to tackle issues regarding I4.0 timely and effectively. From my international outlook, I’m aware that many countries around the globe admire this approach by the German government and some tried to imitate/learn from it, including Malaysia, China and I suppose many more.

Germany has set itself as a role model and showcase country for Industrie 4.0 applications and policies worldwide which might be of great support for Germany tackling one of the major challenges (from my international perspective), i.e. interoperability/standardization. We live in a globalized world and Germany has more than most countries benefited tremendously from a high level of global supply chain integration. In terms of upgrading the industry to a more digitized format or say to process the fourth industrial revolution it cannot suffice to do that individually. International supply chains require alignments in terms of international standards and requirements to have those technical equipment's alongside with clouds and so connected altogether. In this case, Germany is with its advantage in the development of these industrial standards well equipped to negotiate these standards to become mutually accepted. There the German government also finances certain international cooperation projects with important partners worldwide to align on these matters, see for example the Global Project Quality Infrastructure with partners in China, Indonesia, India, Mexico, etc. Another really important challenge both on the global scale but also domestically is data protection. Here, I see Germany clearly lacking behind China or the US since right German but also and especially EU legislation restricts enterprises from fully tapping potentials of digital technologies. Certain service models however have at its core the exchange - sometimes even cross border - of data.

Now talking about SMEs in particular (but those issues might apply to large players too), I believe that a major challenge is education and training as well as the high threshold of investment for certain technological transformations. Especially for firms that want to upgrade a facility while continuing production at the same time. As for government expectations I can only guess that it would be maintaining Germany's competitive edge as being a major industrial economy throughout the fourth industrial revolution. In my view the Plattform initiative shows that the government tries to divert as much responsibility to other stakeholders and make them all engage in finding solutions to which they probably find better answers than politicians by themselves. I believe a very reasonable approach since I4.0 gets extremely technical and complex and political top-down measures without prior consulting with all relevant stakeholders would be likely to fail.

Please again keep in mind that my work focus has always been the international cooperation component of I4.0 and there I'm not necessarily a policy expert for specific German policy issues but rather familiar with the overall framework and how it can be accommodated with other countries (in my case mainly China).

I believe this is a tough one since there is such a large number of SMEs (even in machinery) that it's difficult to assess this. However, since it is asked for the majority of them I would personally place them between stage 2 and 3 since I4.0 engagement usually is a dynamic process rather than a static state. As for government expectations, I suppose they would prefer to have the majority somewhere between 4 and 5, but this is of course not a very realistic expectation to have. Even most large companies would not be at stages 4 or 5 in my POV. Especially larger established firms would have difficulties to process the digitization of the entire organization while maintaining their business operations. However, new

innovative firms such as e.go mobile show that it is sometimes easier to fully implement I4.0 technologies when you start from scratch. Hence, I believe there are huge differences between SMEs in this area and not easy to assess the average or majority status

And then one more remark: Industrie 4.0 is such a buzzword nowadays that many firms or organizations would claim to be a “smart manufacturer” or an I4.0 showcase firm while oftentimes they would not qualify as an actual I4.0 use case but rather plain automation or such

H Respondent 4

Interviewer

What are the guiding policies which the federal government in Germany have published to direct the digital transformation of industry 4.0? What have these policies sought to achieve, particularly in the tool machine manufacturing sector?

Respondent 4

To provide a cohesive guideline and timetables to implement the standards within the organization. You provide milestones in adoption.

Interviewer

Are there any additional Bundesländ policies and aimed outcomes that differ from the federal government? And if so, how do they differ?

Respondent 4

Not that I'm aware of.

Interviewer

Okay. Do enterprises account for the federal government policies and aimed outcomes when implementing industry? 4.0 adoption? Why or why not?

Respondent 4

No idea.

Interviewer

So, when you saw industry 4.0 being implemented? Did you see any? Was there any consideration for what the federal government in Germany wanted? Or was it more along different lines for implementing?

Respondent 4

I would think that that industry meets their needs first and their customers needs. And I would think that government needs are secondary.

Interviewer

Okay. How can policymakers help support industry 4.0 adoption? And if so, what can additionally be done to encourage or to encourage greater adoption

Respondent 4

to allocate a resource that supports that manufacturer and the implementation of industry 4.0 and to have someone help navigate all the different programs and support that's available from the federal government, so like an interface person.

Interviewer

okay. So, in your opinion, why did the German Federal Government adopt an approach which consists of connecting manufacturers, producers, SMEs, policymakers and unions in the aims of promoting dialogue between stakeholders as compared to other countries which possess a diverse target audience and approach?

Respondent 4

Probably you allow them to have the freedom to come up with a with a more targeted and cohesive approach to implementing 4.0.

Interviewer

Have you ever seen firsthand any of the benefits or challenges of this approach?

Respondent 4

benefits? Yeah, I mean, it's predictive failures and downtown's components. So that you don't have the unpredictable downtime, you don't have you don't have production losses. And you know, in advance when there's a problem happening with a machine so that's the big one, you can even plan for your downtime better.

Interviewer

What are some challenges that companies face regarding the implementation of industry 4.0 particularly in relation to government expectations, resource availability within the company? And is what would you suggest that policymakers could do to adapt policy to account for those challenges for a lack of resources?

Respondent 4

Again, have targeted support from within the government as an interface position and provide some sort of financial assistance to those companies to help implement it and expertise and

Interviewer

What are some successes in industry 4.0 adoption, which has been seen widespread in Germany, particularly in this small to medium sized enterprises which are in the machine tool sector.

Respondent 4

The predictability of failures downtime of machines. That's the big one.

Interviewer

Okay? How do you assess the integration of IT departments within industry 4.0 and Germans, SMEs,

Respondent 4

again, resource constraint, you gotta, remember, everybody still has to do their daily job industry 4.0 is an additional requirement on top of still having to do the work, the regular workloads that all these people have. And that's where the challenge comes in with the resource because financially it is very difficult to allocate financial resources to, justify implementing 4.0. You know, if you're a bigger company, obviously, it's easier, small to mid sized companies, their financial burden is quite high.

Interviewer

In regard to that, with the integration of the IT departments, would you say that most IT departments are still being used more in the traditional sense for data security and governance, rather than participating in the transformation process?

Respondent 4

Absolutely it is, I would say it's a side project for them, kind of when they have time to allocate towards it. And it also depends on the urgency set by senior management, for deliverables and timelines. Right? Yeah.

Interviewer

So you would say probably better integration of the IT departments is needed, probably to be adopted into the strategy of the enterprises?

Respondent 4

Yeah. A lot of these departments aren't even working, probably right now.

Interviewer

Does the collection of data on how customers utilize products and how the data is utilized to improve the product commonly practiced in SMEs? Was it done throughout the entirety of the product cycle? So, with the product being utilized by the consumer or was it more like with the service in the maintenance of everything?

Respondent 4

Well, you're, talking about the performance of the product, you got to remember that there are manufacturing components with the beam tools, right? So every so uptime, is monitored and uptime as part of contractual obligations with a lot of customers. And a lot of cases, you have to guarantee cycle times for components. You have to guarantee tool consumption and you also have to guarantee uptime of your equipment, right. So that's all being monitored, because there's penalties if you don't maintain. So industry 4.0 really helps with uptime, because it gives you a predictable tool prior to a failure. So that you can allocate resources to maintain the contractual uptime obligations with benchmarking.

Interviewer

so benchmarked. Okay. And how would you assess the organizational and strategic aspect? So vertical integration and horizontal integration, with industry 4.0 transformation? Is the information being transmitted transparently and autonomously across the enterprise vertically?

Respondent 4

No, I think it's piecemeal. Okay. There’re very few manufacturers that have a standardized plan on how they're implementing it, they're taking bits and pieces of industry 4.0 and they're implementing it as they can and as they have the resources to do so, with the hopes of one day having a fully integrated infrastructure in place.

Interviewer

So you'd say that that standardization is a really big concern for industry 4.0, then if they're just taking bits and pieces

Respondent 4

absolutely. And that's why there needs to be a government resource person to support that.

Interviewer

Okay, because there will be challenges added later on for interoperability

Respondent 4

maybe, the government appoints someone or that the company appoints someone as a project manager for 4.0. And there should be somebody from the government that has regular follow up meetings, maybe quarterly meetings to, to follow up with, with those, with those in the industry that are responsible for implementing it. Okay, to keep the ball rolling. to ensure that they're following a roadmap for government attainment, policy attainment then. Right, and that they're meeting not just the deliverables and timelines, right. So to make sure that is moving forward, that is not the not stagnant. Because if someone's not driving it, nothing gets done.

Interviewer

Yep. Okay, so they need more of a head of a body. Would you say that there's value in enterprise systems that support departments? And if so, should it play more crucial role in industry 4.0 policy?

Respondent 4

I don't have an answer for that one.

Interviewer

The utilization of service-oriented cloud applications in big data applications can provide companies with a competitive advantage. However, privacy and data security is a major concern for the German Federal Government. What is your position on the matter of digital privacy? And how can SMEs continue with the adoption of industry 4.0 while attaining the position which the federal government wants for data security? Is, there currently a challenge for many SMEs?

Respondent 4

Yeah, it's a huge problem and even the proprietary data. That's, being collected from the machines and so on. And that's, an area of concern as well. So manufacturers don't like that information getting out. So they don't like to share.

Interviewer

So with data, with the concern of data security and privacy is more important in regard to protecting from competition domestically and internationally, rather than digital privacy of consumers, and, the individual?

Respondent 4

proprietary information. That's the issue.

Interviewer

So then, what are your perceived benefits of the current policies surrounding industry 4.0 in Germany?

Respondent 4

I don't even know what they are.

Interviewer

And what are the key performance indicators?

Respondent 4

Do you know what the answer to that is, if I don't know what they are, that means they haven't done a very good job of communicating what they are. And that is not filtering down to the organization's right. So for someone not to have an answer to that question it tells you that there's not enough information to get something out.

Interviewer

Yeah, that's why I'm asking those types of questions. It will indicate if that's one of the challenges of the policy.

Respondent 4

Right, because if I say, I have no idea, that means you're not making the information available, or it's not important enough, you know

Interviewer

so far out of all the experts, only two were able to indicate what they are, and what the actual policies are. And then none of them know, any of these state level policies.

Respondent 4

So there you go. That was part of the review. You can see how seriously they're taking it. Right. Yeah, it's a huge problem.

Interviewer

What would you determine as being the key performance indicators in evaluating industry 4.0 adoption?

Respondent 4

while there's industry 4.0 it has got a multifaceted system that affects the entirety of the company. So you have to have a framework and as a project manager, there's different levels of implementation and different departments and different deliverables. And the government knows what those are because they have the expectations of doing that. That's the answer to that question.

you're talking you're talking about industry 4.0 that you're trying to get out with a wide swath of industry to adopt it? Right? If you leave these people to their own devices to implement this, it's doomed to fail. Yep. It's like taxes, you have to set a deadline, and everybody has to file their income tax, that's a good example to use. Because if there wasn't a deadline to follow, for people to file and pay their income taxes, who would do it?

Interviewer

No, of course, this is one of these problems, especially within their policies that you notice. I did a policy analysis from all their policies starting in 2011 which continues to have built off of the or former ICT industrial transformation strategy that then became their industry 4.0 strategy, and the principles that they want are still the exact same that they wanted back in 2011, on what they wanted companies to accomplish, and the biggest thing that they emphasize in their policies was that time is extremely crucial and critical that it must be adopted within the next five years. And they're saying the exact same thing over and over again, without any guidance.

Respondent 4

Right. So yeah, it's really challenging. The government has to spearhead it. If they don't, it's never gonna happen.

Interviewer

I would say, um, do you have any suggestions or input on how the government can support industry 4.0 advancement in Germany, besides the ones you already mentioned?

Respondent 4

No, I mean, that's it, you got to assign a project, you have to assign a resource that has regular meetings with those companies and follows up with the, progress and there also has to be consequences if they're not progressing. Right. I don't know if it's works, right? Because if you fight them, they're just going to kick back. But I would, take this approach. If there's any kind of government programs, assistance programs, or grants that any companies can apply for, regardless of what they are, if it's any kind of government support, one of the criteria to receive any kind of support from the government financial support is that you have to, have reached a certain level of integration and 4.0, or your ineligible to apply for that for any kind of grants or incentives or programs. So that's, how you do it, because fighting them isn't going to work. You just exclude them from being able to get the benefit of certain financial incentives from the government. That's how you get them.

Interviewer

But wouldn't that, isolate different groups like, smaller, enterprises that don't have the initial funds compared to larger ones, like dmg that would have the funds to do it? Or would it be more difficult because you have more traditional manufacturers that have been around 100 to 200 years in Germany, and for them, that digital transformation is a lot harder than for a company that just opens up today, because they don't have to change the entirety of their business process, because their business processes are already modern, and would require the majority of industry 4.0 values to be incorporated into its processes.

Respondent 4

That's why I said in the beginning that the government has to provide some sort of financial assistance for some companies to start implementing 4.0 and also allocate resources to make it happen. Okay. And to me, its a no brainer for this is why? Especially since the majority of German companies are working with SAP Anyway, why wouldn't you have like, an industry 4.0 module that attaches to SAP? So it's an easy transition? Because you could, hit a lot of companies with one shot and just modify it slightly, or just have a complete industry 4.0 module. Why can't you do that? And do it the same with Microsoft works?

Interviewer

Yep. I know these,

Respondent 4

I think 80% of German companies are running SAP. So now you'll be able to transform 80% of the companies by working with SAP. And with Microsoft Dynamics, between those two, you've probably got 90% of the companies. If you're looking for a benchmark and a quick integration, that's how to do it to me, I would as a government, work with them for a module. Okay. And that's kind of how the government has to help. That, may even be the cheapest and the smartest way to do it. Right? Because, instead of everybody

going out and fishing for themselves trying to catch a fish, build on that, then that would be in SAP module I4.0.

I Respondent 5

Respondent 5

So data. If you look at IoT, you could have a manufacturer that creates some sort of an IoT device. And they might have all the data going through their own, whatever the cloud solution is and then, so if you've got a factory, this particular sensor, and that sensor is going to have their own cloud, but then you've got this other sensor in the same device. And that's going to this thing over here. And then you've got this other thing, and it's going over here. It's very difficult to put all that together. The other thing is the first manufacturer, what happens if they decide to decommission their cloud? Right? Yeah, it was another year. Now your data like, your line can be down, because whatever they were supposed to be doing, they're not doing, or they changed. And now, if you're dealing with 100, manufacturers, you've got to go chasing around to make sure everything's always up to date, and they bring out monthly releases, typically these companies. So it's hard to keep on top of all right, so now, instead of just running equipment, you're also an IP shop. Microsoft has a very interesting strategy to deal with all this stuff. So Microsoft has an IoT, basically, in Azure, they have a space where IoT data can flow. And instead of having all of these clouds all over the place, you can have the data right in, Microsoft Azure environment. Microsoft has their own data centers. So in almost every country that's very different from the other ones. So when you look at the Patriot Act and things in the states and accessing people's data, with Microsoft, you've got the data in your own country. And you've got all sorts of tools in Azure that you can use to analyze the data. So there's machine learning, there's AI, there's all sorts of stuff that you can use to build solutions. So there you go. So when you purchase, like IoT type devices, make sure that the data can flow to the Microsoft Cloud, then you'll be protected.

Interviewer

For depending on which country that you're in, the cloud will determine for that accessibility.

Respondent 5

So yeah, so if you're in Germany, Microsoft has data centers in Germany.

Interviewer

So it's following the European Union's data protection

Respondent 5

rules? Absolutely. Now, if you're in Taiwan, there's a data center in Taiwan. So at one point, I think it was last year, the year before they were opening a new data center every week. Okay. Yeah. So if you contrast that with the other large one, so it would be Amazon. So Amazon, actually, they might have data they're also competing against a lot of retailers, manufacturers. So companies are saying, why would I want to put my data there? If they're basically giving the money to compete against me, and I really don't know what they're doing with my data. Right. So with Microsoft, they're not making money off your data. They're, basically making money off of the software and Azure environment, not technically the service. Yeah. Okay. So it's, it's all about architecture. So it's, not just putting IoT devices in and having them talk to each other. And you really have to think through so companies have to think through where their data is going to be, and how much work they really have to do to keep things going and what other things they want on top of IoT to make sense of everything.

Interviewer

So, maybe from your perspective, what would be some of the successes that companies have been able to achieve or attain from, implementing all these like Microsoft Dynamics, and other systems.

Respondent 5

But what we're doing, like there's a lot of success, I'll give you one though, XXXX. So they're a company that sells ice, okay. So if you have a party, and you want to go and get ice, you go to a convenience store and you know, those coolers and there's all those bags ice. That's okay. And in the wintertime, they had 50 people taking calls across. So basically, in different call centers. I think they had a couple. And then in the summertime, they spike up to 150 people. Because they got a lot more calls. And they do two things they do outbound calls to say, you scheduled for a next day delivery. Tomorrow you know, your icebox is near the bottom now. Or should we wait till next week, they also will take calls from places that say, hey a guy just came in and bought all the rest of the ice, we need more ice. And so the you'd handle an inbound call, right? What we did is instead of having to call in you just to get your cell phone out and type need ice, and text it to XXXX and ice would be scheduled to be delivered.

Interviewer

So you're putting the responsibility on, the gas stations more or less to make the buy.

Respondent 5

Yeah, they called in anyways over the phone. But you had to have an agent physically answer the phone. So now he just texted this, you don't really need to talk to somebody right now. There's no need, you can just schedule it or book it like you can book an appointment online as well.

Respondent 5

Yeah. And instead of calling the gas station or convenience store, or whatever it is, and you know, they're servicing customers, so they're busy. They're just texting out, hey, do you want us to deliver the ice tomorrow? And the person would text back yes or no, or whatever. The other thing is, we also put functionality into that into the IVR. So if you did call in, and it was the IVR, Say Do you know are you calling in about ice? Yes. You need more ice? Yes. Okay, it will get delivered tomorrow. Okay. So at the savings are, that instead of 150 people in peak times, they'll probably be able to get away with their 50 all year round.

Interviewer

So they don't need seasonal workers anymore now that's interesting, or they need they need less

Respondent 5

So we're just in the process of doing that. Now if you look at another call center example, we did sell in the Caribbean, so there are large Telecom, they service 20 countries. So it used to take six weeks to train a new rep, because they had to teach them how to use 46 applications and when to use them on their desktops. Okay. We created something where they call in and it recorded why the person's calling, and then it puts the application that they need right on the screen. So that training time went down to four hours from six weeks because it's automated.

Respondent 5

We've done a lot of these things. So we're doing stuff in government now. When you look at IoT, I suppose we couldn’t do a project without it. I haven't done one recently, but essentially, you can have sensors like we were talking, with a janitorial company that cleans washrooms. So you know, if a washroom is dirty, you report it, but we could put a little IoT device in the washroom and just tap it. And then that would then tell their CRM system, hey, this washer needs to be clean. And then somebody could be dispatched to clean it.

Interviewer

Yeah. And you hit a button? Yeah., so that could be an IoT device. Yeah. some of the IoT devices that I've talked to some companies about with, what they're working on is for to deal with maintenance for the machines. So we know the ware-time on the machines, how many products have gone through that one machine. So if you're going to need a new spindle or new axle that needs to come in. They even have some, The I think it's the Porsche plant, which is really impressive for their systems of IoT they know almost every single bit and screw that's inside the factory at any given time. Porsche has plant in Germany, and they actually know that because the robots are assembling the cars, they know how much force is being done on each nut and screw into the car. So that it's actually being given to their service and maintenance team. So they can look back later and say, Oh, that's exactly why your car's broken. The robot had twisted

the screw too tight, and it cracked this. So we're going to repair it for you. And this is, like the full optimal industry 4.0 kind of assembly line others gearing towards.

Respondent 5

Now we did work with a company called XXXXX. So they're based in Germany, and they do, you might have heard of them. They're the largest sales force in the world, which is kind of neat. And they sell nuts and bolts and, but they have these bins that they put into companies and they stocked them with bolts and everything. And they have a person come around and detail them. So you'll check out these bins and say, Okay, well, you're low on these nuts. you're low on these bolts, and then they ship them out. But I believe what they have is IoT type scales, and each one of these at some places, and when the bin gets too light, then it replenishes

Interviewer

Oh, wow. Okay, I have some precedent. Yeah, it's really keeping track of everything. Yeah. But actually, one of the questions I was actually hoping to ask you is, what value do you see in enterprise systems that support departments? Especially in relation to industry 4.0? So like different enterprise systems, you have like the CRM systems or the executive support systems? Like ESS? what do you do you see that these should play more of a value in industry 4.0 and digital transformation? Or do you think they should be passed along? Because this is kind of a discussion that is occurring? Should there be more emphasis on implementing more enterprise systems within industry 4.0? Or should it be geared more towards the technological machine perspective.

Respondent 5

So, I don't know as much about industry 4.0 as you do. I'm not that much into manufacturing, but what I can tell you is where companies fall down nowadays is architecture. They have all these different systems that don't talk to one another, and then in order to get any value out of things, they have to build interfaces, and interfaces are very expensive. And every interface is a weak point. It's something that can go down. The other thing is management. And companies often make decisions based on looking through the rear-view mirror. So those are lag indicators basically, ever heard of balanced scorecard?

Respondent 5

Can you refer to Harvard profs that wrote this thing called balanced scorecard years ago, and a lot of companies followed it over time with

Interviewer

Toyota, I believe, uses it.

Respondent 5

Well, they may have done that, I actually worked with them on at Molson black, and they wrote the article, which was kind of neat. And the idea is lead, and lag indicators. So you really should be making your business decisions based on lead indicators, because a lead indicator will tell you this is happening now. And you have time to adjust it before you don't have time to adjust it. A lag indicator is what happened last month, you could never change it. Yeah. So, a lag indicator might be sales. So you could have, let's say $3 million dollars worth of sales in May. And if I give you a billion dollars, you can't fix the sales. Yeah, there's no matter how much money has been, you can never go back and fix the past, right. But I can tell you that your sales team is doing half of the lead gen calls that they were doing last year. And for every lead gen call, like there's a ratio of business sold coming through the door. So chances are in six months time you're going to be at about half the business that you are today. Yeah. So can you do something about that? Well, absolutely. Right. You can figure out why are the sales reps making less calls? Well, maybe You get so many projects on the go now that they started project managing and not doing as much time selling. So you can fix that by reassigning work, right. It could be a training issue, it could be maybe some of your best lead gen people left, so you have to replace them. So that's a lead indicator. Okay. So in IoT, I would assume a lead indicator would be a piece of equipment that started vibrate. Yeah. So a lag indicator would be the equipment broke down. So companies are the same way, what you want to do is you want to focus on decision support of the lead indicators, and narrowed down to the ones that are really important. And that's even more easily said than done. But for companies that have done it, they've really grown. Okay, so. So I would, give you leading light indicators with balanced scorecard. And, as well, architecture is an example. And you have to think through your architecture.

Interviewer

Yeah. I can agree with the architecture, one of our courses we have to take in my master's was Enterprise Architecture management. And for that we had different assignments. So even on the exam we had, to do a whole entire transformation of a company. So they'll explain to you and the thing. They had some guy come in, they put in all these different systems throughout time. And then now it's all completely entangled. And how does an update something? So how do you go back and do this because there was no proper architecture from the very beginning, especially with one when all technology first came out? There's this kind of bits and pieces tangling together. And now that we want to update it, and we're talking about connectivity? Well, nobody knows what's connected to especially if these people who put it in aren't working there anymore.

Respondent 5

Yeah. So but that happens all over the place and these are the worst. So somebody wants a new CRM system, renew whatever. And we ask what are you using today? Oh, we've got this fantastic piece of software that was that we've developed over the last 17 years. Really, and they kind of show it to you, and

it actually looks old, but it works. And they said, Yeah, but it keeps breaking down all the time. And the person that did it left five years ago, and every time we try to make a change to it, it breaks a whole bunch of things. So we just want to replace it. They're the worst ones. Because you can't. you can't just go and put something new in and replace 17 years of history, because often there's functions they don't even know whether it exists. And it might be that once a year they run this magic, they press this magic button and sets up the whole sales environment for the year. What does it do? We don't know. They don't even know that freaking button exists. Yeah, so those, are the worst ones. You know it. There are companies that have gone and custom develop stuff. And everything's custom, like, even a button on the screen, somebody coded the button to be there. So that people do things now is with a configurable environment like the Microsoft Dynamics that we do. So 90% of the code is already done. And all we do is we configure it to flow the way they need it to flow. So there's contacts and companies in it, there we can create custom entities. But if a person that had never seen it before, goes in and looks at it, they'd be able to figure it out, especially if you document it pretty easily.

Interviewer

Because it's more of the basic template of the Microsoft System, and then you configure it based on the needs of the company.

Respondent 5

Right? That's right. And there's things like it works. So if, if you email me and I've got you in my system, right click on your email, and it shows me your record in the system, right? And I will look okay, and then they can jump to your record rate from there. We didn't call it that. It's just there. So if we go into a company that has dynamics, and that's working, I don't have to, if they have a problem, I don't have to try to figure out how they did that because Microsoft did that. Or maybe Microsoft has something called power automate, and power automates for integration. So we don't have to build software that will integrate. We already know that that's there. So it's essentially there only certain points of failure or that you need to extend. So it's a lot easier. Microsoft's IoT cloud, there's actually a way of doing that. So you don't have to worry how to call or reference the devices in the cloud, because that's figured out for you. You just have to worry about can this device put its data in the Microsoft Cloud? Okay. And if you've determined a certain architecture, and wherever the manufacturer that devices doesn't go to the cloud, don't buy that brand.

Interviewer

I was, talking to somebody else in the field of application. And he had mentioned that you find a lot of companies, they come to you, and they say, we want the cloud application from Microsoft, or we want this, we want that. And they actually don't know if it actually will produce any value for them. They just read that somebody else has, and they say we want it. Is this something that you normally experience as well?

Respondent 5

Yeah, so the trick is that it's just software, right? It won't do anything for you. it's not as bad now. But at a certain point. We had companies say, well, we put in Dynamics, and it didn't give us any value.

Interviewer

Yeah, they expect technology to give.

Respondent 5

Yeah, well said, and they said, well, we didn't change any of our business processes. It's just all we're doing is we're entering data into this, then we're not even using it. Yeah. Okay. Well, let's take a step back here. What did you want to accomplish? Well, we wanted to increase sales, and we wanted to do this and that, okay. In the project, show me where you had these objectives, and how you were going to meet them? another answer back would be well, we just thought the software would do that. And it does, right. It's a business process. You know, the XXXX example that I gave you, where we we've cut down on the amount of work and actually make customers happier in the meantime, because they don't want to wait on hold. PDO is a big Canadian accounting for BPO actually was in there. And they were replacing a system that had been homegrown and had been around for one of those 17-year-old. And that 17-year-old system could process a request for ice in about a minute and a half. The DDoS solution when they went live, took three minutes. So, guess what happens to your 150? employee count? after that?

Interviewer

You need more? You need 300 employees?

Respondent 5

Yeah. Right. doubled your time. absolutely. So then when we took it from the three minutes, and brought it down to zero minutes, what happens?

Interviewer

You don't need those employees anywhere you can cut them.

Respondent 5

There you go. now unfortunately, this is the outsource in place that they were getting outsourced. But you know, that's, architecture, this thinking through what the business objectives are, that's business process. We're just putting IoT devices in to measure vibration on a machine. It actually doesn't do a lot for you, if somebody has to sit there and look at every IoT device to see. How's it doing? Yeah. Oh, I've got a number of 3800. Okay. What was it yesterday? I don't know. It's just says 3800. Now. So, you actually have the IoT device alone isn't enough, you have to put some sort of intelligence on top of it, that will then flag

issues, and then you have to put some sort of monitoring on top of that. And then you have to have some sort of field service on top of that, to dispatch people to fix stuff. And then you have to put something on top of it to determine the degree of risk. So, if there's a part that you need, and it's really expensive, and it's got a six-week lead time, and it starts going, you better react to that thing quicker than the dollar 50 fastener that can be replaced like that. You know what I mean? You have to look at business risk and tolerance. And some of these things, you might want to have a spare one sitting on the shelf or two, just in case,

Interviewer

IoT systems that can predetermine service or breakdown is really important, especially, well, what they've learned right now is actually with repairs for these CNC machines. So, prior to the pandemic, a majority of the CNC machines are actually produced by German companies or Japanese companies. And a lot of them have merged. And they pulled the service department out of North America, and they brought it to Europe. And they were just flying guys in to fix the machines in the factory. But with COVID, that presented a huge problem because, the borders were shut at first. And then now you need a two week, or 10-day isolation time, you need a COVID test, you need all these types of stuff. So, they've been having factories that have been down. And when these some of these factories that are down, it kills them, the manufacturing is completely gone. And so that's been some of their biggest problems. And well, we've had these machines that can kind of warn us ahead of time with something's going to break so we can kind of get something done beforehand or tried to have something shipped and have a third party fix it. And they've realized that with COVID maybe it was a mistake having everything outsourced to Europe. Yeah, but these types of systems to warn them it's created a huge thing, because these machines are over a couple million dollars each. So, when one of them goes down, it's their whole system's down.

Respondent 5

So Microsoft has some solutions for that. By the way, have you ever heard of a HoloLens?

Interviewer

no, what's this?

Respondent 5

Oh, you should google it, because it's amazing for manufacturing. It's, like an Oculus, sort of goggles that you wear that you can actually see through them. Okay. So it's almost like sunglasses. So you put these things on, you can see the machine in front of you. But you can have step by step instructions show on the screen. So, when you're working on it, you don't have to get a manual up and look at it. The other thing you can do is get an engineer in Germany, to be seeing what you're seeing. And they could be instructing you on what to do.

Interviewer

Okay, that's interesting.

Respondent 5

Okay. And they even have a coordinate solution that works with dynamics field service, and you basically hold your smartphone up. And the engineer can see what your smartphone is looking at. And it can actually show you, like draw circles around what the what the press and stuff like that on the screen as you're looking. So, you're looking through your screen.

Interviewer

Okay, that's interesting. I know, they have, I think something similar to this, in manufacturing that some of them have produced it for their own machines, on the other on their command, where they can do a remote technician, from Germany to try to help you troubleshoot it. But that only works if it's a technical problem in the machine that they can fix with programming. It doesn't help when it was the physical part that needs to be changed.

Respondent 5

But what you can actually do is, if you wear these lenses, somebody can walk you through what to do. I'll just show you.

Interviewer

would that be more like augmented reality?

Respondent 5

So let me just go back in for a sec. Okay, so that's basically showing the phone and on her phone is showing what to click because the person on the other side is, is doing it.

Interviewer

That's impressive. Okay. Isn't that amazing? That's really cool. Yeah.

Respondent 5

So that's the phone one. And let me see if I can get the Lensman for you. Okay, so this is see through DC that area? Yeah. And these are cameras up here. Okay. So, she's looking at the box, and she can actually bring people in. So, they then can see exactly what she's seeing.

Interviewer

That's really cool. And then these, these glasses are absolutely amazing. And then the person on the computer can draw the lines on what to move into indicator.

Respondent 5

Yeah, so you've got sheet drag one of the desktops to the right-hand side. So, all she has to do is turn her head and see the desktop. So it's as if she, has the manual floating in the lab. And here's your here's your IoT stuff.

Interviewer

Yeah. The sensors, the input from the sensors. Well, this is really cool. So, this is more of like, augmented reality. I could press buttons in the middle of the air. Yeah. that's a really big topic right now in digital transformation. And all that is augmented reality and, how this can play a role in healthcare, policy, and service.

Respondent 5

Yeah, well, it's COVID. The impacts of COVID will live on and I think they're good impacts. You know, if I'm a repair expert in Germany, why do I have to fly to Nebraska to change a part on a machine? So sure, I'm an expert at it. But usually, it involves taking a few screws. Yeah, lubricating something, putting it in putting the screws back. Now, the guy in Germany needs to be sent out, because if you screw up, you just blew up a $3 million machine, right?

Interviewer

Yeah, it's liability.

Respondent 5

Right. But if I actually supervise somebody that's competent. Okay. you know, maybe there's a checklist that I've got, I'm actually taking a film of what he's doing, but I can set up a digital recording. I'm covered. And I don't need to charge. Because the time is not just the airplane flight. So it's, you know, 1500 bucks to get over plus the hotel's day plus the car, plus the food plus that, fix it just in travel alone, it's probably six grand, too expensive. Yeah. And then the time to fix it. I'd much rather spend two hours with somebody virtually, and help them out

Interviewer

they spent a lot of money and even if you did have, you could even use it in another sense of having your technicians out. And if your technicians have trouble trying to repair something and you're the boss, they

can call you directly to resolve the problem. Especially when they have, bigger backups or problems that they're facing.

Respondent 5

Yeah. So, you know that's the future, right? You don't need to go out every time. So you'll, go out to build relationships. But you don't need to go out and do a whole bunch of things you used to have to go to do. And so, life should be better for people now. The site is going to change a little bit. There's going to be shifts of wealth and the whole bit, right. So skilled workers are probably going to do better than other people. But it's gonna happen whether we like it or not, so we might as well like it, and try to get into roles where we can embrace it.

Interviewer

Well, it's actually Interesting. So, Germany has two policies that are out surrounding industry 4.0. So there's one for the manufacturers, and then there's one for the social impact of it. And so they're already talking about what type of education and training will be needed. What impact will this be on salaries were audited website. Yeah. So, they have two separate policies one on for the manufacturers and a one on how to deal with the implications of this complete transformation. And they're talking about how the future manufacturing, this will be a possibility to move the manufacturing back from Asia to Europe, North America. And then on top of it, the employees that you need, they're no longer going to need, you know, the traditional manufacturers are having to work by hands, now, it's going to be a guy have an iPad, more or less, or a tablet, controlling centers, and ensuring everything's being moved around. And so, it's a question of, is it gonna be humans working with robots or humans controlling robots? How will it work within the manufacturing sector, and they're kind of discussing this type of policy already in Germany?

Respondent 5

So,, the interesting thing is a couple of things. One, on the manufacturing side, the way that we've geared up to build stuff for you have a whole factory that will produce this one part right off these machines. And you know, you think of a car, you might have a whole line that just does the door of the car. So it's something bends the metal, something welded something. If you've got the ability to print parts out, right, and it parts in metal, and that's you can do it now. But it's just expensive. But as we bring that down, the way that we manufacture can be very different. And it can almost be whatever on demand, instead of having these parts all over the place, you're going to simplify. So now we don't you know that the cheap labor and in the east, you don't need it anymore. So that's one thing. That's kind of exciting. The other thing, and this is something that I think about, you know, read about it too much. But if you think of clothing, so 100 years ago, if you needed a shirt, you'd go down to the local tailor, and you'd say I need a shirt. And they'd say, okay, what kind of fabric? Would you like, you feel three feet? I like that. Okay, what kind of pattern do you like? I like that. Okay. And what design do you like? Well, I like that design. And then you go back later in the

day, and your shirts made a very expensive shirt, this shirt is made, right. And then we started mass producing these things. So you go to the gap, and they've got 15 smalls, you know, five mediums, they just ran out a large, and they've got 100 extras large for some reason. So, they make all of these shirts in the east. And then we ship them over onto the painters. And they're even calling it like, disposable, where like, this stuff is so cheap that some of the people wear two or three times and then they throw it out or it sits in their closet forever it just didn't wash like they thought it would or they don't like the pattern as much as they thought or, whatever. So, what I think is gonna happen is we might even not see on shoring of clothing. That will be the clothing that we had 100 years ago, where you picked your fabric, you picked your design, and you picked your pattern. The only differences are robots gonna make it that and I'll still be cheap. It will be dirt cheap. Once you can make stuff in volume, it's the costume that materials plus five minutes on the robot. Yeah, right. So just think about that. Think of all of the shifts in the trains, and the trucks that are carrying all this stuff, think of all the stores. All the retail clerks, think about all the people that are making that in those countries like this. It's huge. It's a huge supply chain.

Interviewer

that's interesting within the manufacturing sector, because industry 4.0. It was invented in Germany, by the German government. So it's like they call it the first industrial revolution in which it was planned. And designed by the by the government and academics and manufacturers. So they're actually really trying to control the direction of it so they can decide really where it ends up. And so I think we can kind of see which direction it's heading in. I think they're trying to really pull manufacturing back. They've just opened up a giant microchip factory in Eastern Germany.

J Respondent 6

Interviewer

Okay. So, the first question is, what are the guiding policies which the federal government in Germany have published to direct the digital transformation of industry 4.0, what have these policies sought to achieve particularly in the machine tool manufacturing sector?

Respondent 6

That is probably something that I, failed the most with. Like, I mean, I published the report in 2018. This was published sometime around March or April, but I basically wrote it in November, December of 2017. So everything, like almost five years old, or not four years old by now. And the, policies like then they had some, more theoretical or philosophical like concept notes and drafts, starting with the high tech strategy back in 2006, where just like, they basically sat together and fantasize about how industry could look like and then it got more concrete over the years they have written I can read out the names to you, I probably don't know too much about the content anymore. But I guess the most important one was the high-tech strategy 2020, which was published in 2010. And then, the last strategy I uncovered in my research was the

Neue high tech strategy which was published in 2014. And There was in terms of policy, and after that they got more confused, especially in Plattform Industrie 4.0, which was also policy guided but was rather like politics.

Interviewer

Are there any additional Bundesländer policies and aimed outcomes that differ from the federal government? And if so, how do they differ in their end outcomes and methods of implementation?

Respondent 6

As far as I know, back then there weren't any additional Bundesländer policies, but you always had these cross-cutting industry researches that they've always involved in with different actors. I mean, all these policies, they've always done, like co drafted with industry associations whatsoever, and they had a heavy bias which I cannot understand. Even less so. But these two that they were particularly, strongly involved in the policy process, but I, don't recall any like that they had any own policies or strategies.

Interviewer

Can policymakers help support industry 4.0 adoption? And if so, what can additionally be done to encourage greater adoption?

Respondent 6

a very broad quest question. Yes, of course, probably a gazillion ways to do so. Yeah, we had consulting bodies which was something that we frequently, aligned to like the policymakers just established like a forum where different private sector companies could just meet up and exchange about industry and implementation and adaptation, then, of course, it's all about money. Like if you can provide a policy that sets up funding, standardization. That’s very critical, especially when it comes to like, state of data and regulatory policy obviously. Mainly, it's something which I labeled as soft instruments, and it left networks and something that we then called test beds that I'm not too familiar with anymore, but I guess it was about cooperation initiatives between universities and providing infrastructure and chair infrastructures. Where it because obvious, industry formula is a very financially intensive field of research, because it involves heavy machinery, and it takes tech. And I guess, they were trying to facilitate that by building labs that could be used by different partners. So yeah, regulatory policy instruments, economic and financial instruments. And, these soft instruments when it comes to training and research.

Interviewer

In your opinion, why did the German Federal Government adopt an approach which consists of connecting manufacturers, producers SMEs and policymakers in the aims of promoting dialogue between stakeholders as compared to other countries which possess a diverse target audience and approach?

Respondent 6

Something that I that I always found very particular about the Germany's approach and our strategy was that it's as much a bottom up strategy as it's a top down strategy because like the, players especially in the SME environment, they're very strong headed because they're like old traditional firms that have been around for a long time and they like what they do, it usually works. They're leaders in their fields and so it's you have to get them on board. And they have to like providing them with a top-down approach saying this is how we do it in like German industry and this is the network and you have to adapt. Probably wouldn't work. So you always had them on board from the beginning so that they could provide the insights and you develop a strategy with them together.

Interviewer

Moving on to the interview questions for research. Question number two, what are some challenges that companies face regarding the implementation of industry 4.0, particularly in relation to government expectations?

Respondent 6

I guess from top of my head, one of the one of the main problems was that like, frankly, also, I struggled with the definition of industry 4.0 in the first place, like what is it that we're dealing with? Is it like the Internet of Things that, like, if you have Wi Fi connected with the robotics and the people just like, it's hard to grasp the full concept of industry, foreign industry? The direct benefits to your company? Because what, does it take you like, what do you have to invest into to be like industry foreign already? What are the direct benefits to your to your company? And also, where do you start? Like us? I mean, you work full time you have a company that's running that is producing by good margins. And then why do you need to care about that? Like, additionally, do you have to hire someone? Who does it for you? Can someone do it on the side? It's just, I mean, 2017 speaking, so you can hear but like back then, I guess many of the companies they just didn't see it as like the most important thing to get ongoing with.

Interviewer

How would you suggest that policymakers could adapt the policy to account for these challenges?

Respondent 6

Probably also, like movies, I try to think about, the most important it's a bit weird, because maybe, like, many things have changed in the field by now. But like looking at back then when I when I wrote the paper, maybe to be from I am feeling that they could have been a bit more concise and a bit more outgoing because it I guess it just needed a lot of explaining as well, for these manufacturers who like was said word clouds in the field and didn't have lots to do with industry 4.0, were probably doing like producing that machinery

parts for the past 50 years, and they've been hugely successful, and to just to visit them to show them concrete examples. And then to say, here's the funding part give them investment and that'll be the outcome.

Interviewer

It's different. Yeah. I think that's interesting, because a lot of the policy as well, from the work that you have done, and then the work that I looked at, for my policy analysis of the current policy for the 2030 vision, a lot of it is still based off of the old policy. It's still talking about infrastructure, you know, applications, it has very much the same theme as it has been continuously built upon. It's now adopting more of a focus on integration or preparing for integration. It's in between those steps of the policy focusing on now, are we going to start integrating with other actors, or it's kind of having the landscape designed for it in a technical sense, so that they can actually move forward with it, where, as before, it's kind of where you'd mentioned, is talking about frameworks and how to get this started and rolling. So it's, starting to move, but it's a very slow train.

Respondent 6

Yeah, I guess I mean, there's not a policy recommendation, but I guess what also really affected is the poor state of the of the German infrastructure when it comes to cables on the ground. Like it's a must it is just too slow but you can never have real time production updates from a remote facility somewhere taking another from this land, it's just not working.

Interviewer

How do you assess the integration of IT departments within industry 4.0 in German, small to medium sized enterprises?

Respondent 6

I guess that was not really part of my research and I could only just guess about it.

Interviewer

In your opinion, what level would you say most small to medium sized enterprises are on in Germany? Is the level that you indicated the same regarding what you believe the federal government would want most companies to be on? And then I have the stages. So it's stages 1 to 5. So in your opinion, what do you think most small to medium sized enterprises are on? And then what stage Do you think the federal government would want for most companies to be on? In regard to policy? Or the policy that

Respondent 6

there's probably a gap in what the federal government believes. Again, I have to qualify, I mean, the expectation differ in a way that many of these SMEs are, in a way quite advanced, but not in a way that the government thinks they should be in, not in a way that they like. Each of them is following their own strategy, maybe like in a smaller cluster with their suppliers over there with other companies in the field, but it's not really coordinated. And they wouldn't score high on the on the SIMMI scale. And also wouldn't score high on the on the governance expectations. Because which, in turn is probably a failure of the government as well, because they, I mean, they respond to economic needs, and they just did what was beneficial and economically sound to them. And if the policy wasn't there, they just did it anyways. And now the policy is coming, or the policy was there back then, as well, but they just didn't find them at the right place in time.

Interviewer

Yeah, they were not connected at the right time. So what stage would you indicate for company most SMEs on average to be on in Germany?

Respondent 6

I can only guess. And then not having lived in Germany for the past four years. We held them that way. So yeah, maybe it would be very unscientific.

Interviewer

That works. Okay. And I think this question, the utilization of service oriented cloud applications and big data applications can provide companies with a competitive advantage. However, privacy and data security is a major concern for the German Federal Government. What is your position on the matter of digital privacy? And how can SMEs continue with the adoption of industry 4.0 while attaining a position with which the federal government wants for data security is currently a challenge for SMEs.

Respondent 6

I guess so because Germany has always been probably will always be a country which population is very conservative when it comes to data protection and is also very sensitive when it comes to infringement on data security. However, with a qualification that mainly concerns personal data, so like if it's, your address your younger status whatsoever, then there's some progress being made. Also, we had a huge discussion when it came to the corona app that was developed like a year ago, I don't know whether you follow that, or the lab centers with the corona test. So there is some discussion that like, you can't have both, like full digitization and complete data protection at the same time. So I guess that at least you can have a more informed policy discussion about that, then you were able to have a couple of years back where you had, like very fundamentalist views, you had the liberals who were all in for digitization and you had then, like the greens or some other parties who are very keen on data protection, and now you have more people in

the public sphere, and also amongst the political parties who have quite informed opinions about the whole data and so on. I mean, yeah, I guess that the discussion is still ongoing and will be ongoing forever. But it's gained in quality.

Interviewer

That's interesting answer. But yeah, I know, that's definitely a really big thing in Germany is data privacy.

Respondent 6

You see that last part? the fact that, like, most people prefer paying cash over card because they don't want to be tracked?

Interviewer

Okay, so we'll move on to the interview questions for research number three. So what are the what are your perceived benefits of the current policies surrounding industry? 4.0 in Germany?

Respondent 6

At least they have one, I guess it's a benefit. So, I mean, they saw the topic and they tried to seize it. And, I mean, back in 2017, I know that like a lot of people were interested in German industry community strategy, and that they approached German policymakers and to ask them, like, how do you do it. But like, from within our department, when we were quite fraying, we knew that it was like, a lot of time and very little action back then. But at least they had experts sitting together and trying to make sense of it all. And then so I guess you can't really undervalue the fact that like, already back in 2002, and all the way to 2017 you had people who were aware and you had like significant funds being poured into it, even though the results were probably not too startling. And then probably also that you have, like an industry which is ready to participate or which would be keen on participating but it's not really like benefit of the policy. Now, if I recall something else, I'd say but as of now perceived benefits are, I mean, it also wasn't a realistic strategy. So they didn't only look at very specific aspects of industry, but they always try to embed it in a broader high tech strategy. I mean, I can't really say whether that worked, but at least from the beginning they said okay, we can't really say we focus on car manufacturers only. But we focus on industry as a whole. And that also means that we have to focus on data security that we have to focus on, like extending our broadband network. And yeah, it was a bottom up which was specifically designed for Germany. So they just like didn't look at other countries and copy the strategy one to one and try to implement it in Germany, but they said okay, let's just take the universities take the industry and key players take the associations take, I know some unions and then we just like meet on a regular basis and try to make sense Let's continuously discuss and figure out what are the challenges that others are facing and kind of work through it? Like, especially the inclusion of SMEs, probably as well. I mean, it makes sense to the German market

where you have lots of them. I mean, they were also not excluded, which could probably hadn't, quite, quite easily.

Interviewer

Yeah, the SMEs are a huge part of their about almost 70 or 80% of German economy. So it's very important to include them in discussion. So would you like to speak on what are the key performance indicators in evaluating industry 4.0 adoption,

Respondent 6

I just thought of the SIMMI so maybe that

Interviewer

SIMMI could be a means of doing such for maturity index. Also, Germany's now published RIMMI 4.0, which is the reference architecture model, and that's being coined as the current standards for industry 4.0. And they're pushing into Singapore and other countries globally to work in partnerships to create now a global standard for it. So they're still again at the very beginning of a framework from what I found. And I think you've kind of already mentioned a little bit on can the current policy be improved? and How so? So do you have any more suggestions or input on how the government can support industry 4.0 advancement in Germany, that you may have not mentioned prior.

Respondent 6

I mean, that is probably also my perspective working for the press department, at the German XXXXXX and so far as I can tell the I4.0 industry topic and like a large part of the population have not even heard about it, maybe, it could be of any help, or they could at least consider like starting a public campaign about it and then get like other people outside of industry talking about and then just like how to generate a push that then carries industry forward. Because I mean, it is very, scientific and probably also very boring for most of the people. But you never know which synergies you can make use of if you just try to make more widely known. Yeah, and then another challenge as well as internationally, there's just many different terms for industry for both in America smart manufacturing or smart industry. And so and then, are you referring to the fourth industrial revolution or industry 4.0?

K Respondent 7

Interviewer

So the first research question we have for the first question is what are the guiding policies which the federal government in Germany have published to direct the digital transformation of industry 4.0. And what have these policies sought to achieve particularly in the tool machine manufacturing sector.

Respondent 7

And this is a little bit more complicated. For us, as the chairman, policies are also internally influenced by European strategies and of course, in Germany, there are things like the GDPR, of course, but it's now on at a European level as well. And what is also under read comes around redefinition or extension is something that is called the machine in originally in which is the machine directive? I don't know if you have heard of it. this the basic law for how machines, what security and compliance wishes they need to fulfill, etc. And of course, there are different data strategies, data governance acts as the German data strategy. Of course, then there are the different funding programs that direct the different research and development activities. And also big issue is the attire x endeavor. And this has also been linked to the European data strategy, trustworthy AI strategy, of course. But these are basically the two main policies that are now guiding us. And in the industry, for co sector, or, let's say, one of the major ones, or they might be others or others as well. But these are the major ones that are now heavily influencing different activities and the companies because they have some wide-ranging consequences.

Interviewer

Okay. Yeah, there's a lot of different policies, what I found in the research, there's different ones at the EU level, there's ones at the German level, at the state level, and then you have digital policy for ICT, you have machining policy, and then you have even just policy with like Plattform Industrie 4.0, where they publish it in relation to the ministries and just selectively focus on I 40 transformations. So there isn't really a one size fits all approach for the policy, it seems to be really scattered out.

Respondent 7

Right. I mean, the most important thing to consider in terms of industry 4.0 is interoperability and data continuity. So all the different endeavors, of course, should aim at fostering or motivating participants to invest or to look at what is, yeah, basically, in terms of data continuity. And in terms of industry 4.0, you're probably aware of the Plattform Industrie 4.0. And this, for example, has already some years ago, published that, at least 10, basic foundational application scenarios. I don't know if you know them.

Interviewer

No, I haven't heard of this.

Respondent 7

Okay. So if you go to the website of platform industry 4.0, or if you just Google for the foundational application scenarios of industry 4.0, there are 10 basic scenario, something like circular economy, adaptive factory, etc. And, of course, the different legislations etc. We need to address these aspects in some way or the other, or we need to be interlinked with them. Because if, of course, the legal issues, counterfeit,

basically these application scenarios, then industry, 4.0 will not be possible, or with some big trade off, or drawbacks.

Interviewer

Yeah, that actually sounds very similar to a lot of other policy, I4.0 2020 vision, I believe, hits on those points as well. Actually, within my research so far, what I've been able to conclude is that I did conduct a policy analysis of previous policy back into I think, 2013. And you can see that a lot of these objectives are continually being put into the next, year's focus on what should be done.

Interviewer

Okay, so the second question, are there any additional Bundesländer policies and aimed outcomes that differ from the federal government? And if so, how do they differ in their aim outcomes and methods of implementation?

Respondent 7

I'm afraid I cannot mention you any in particular here comes that level. I'm not working on that level. I would assume that they're offering someone something strategies. I know that there were at least some varying funding programs. And of course, they need to be aligned with the federal funding programs, or the federal strategies. Yeah. I mean, informer barrier, there might also be some other things. Because in Bavaria, everything is a little bit different than the rest of Germany. Yeah. But, nevertheless, they need to align with the federal strategies, but I'm afraid I cannot name particular ones right now.

Interviewer

Yeah, there's not as many as the federal directives, you can find quite a few in Bavaria and Baden Württemberg. And but more of their policies currently are directed around, we want to be the best of regions and Germany for the manufacturing sector. We want autonomy. We want interoperability. So it's more of they do have research funding programs, but it's more directed at the federal level, in partnership with the federal level normally. Right. So for the third question is do enterprises account for federal government policies and outcomes when implementing industry for adoption? And why or why not? Maybe you might know, experiences? Is this really something that's considered with what the government wants to have achieved? Or is it more this this make profitability for us?

Respondent 7

Yeah, I would, I would say from my practical experience, it goes more for the latter. Okay. I think this is a personal opinion, that, of course, the public political strategies, especially in terms of data, strategy, etc. But all eight forms using vendor lock in creating transparency, etc. This will, or should, eventually, it has a tremendous effect on the different manufacturers in terms of providing data services, etc. And, of course,

this would then require some change in the mindset as well, in the different companies. Right now the argumentation goes, as you said in the second part of your question, it's really like, if we do this, will this be profitable for us? Does it have any benefit for us? If not, then ignore the government as long as possible. So, but unfortunately, this leads to the big disadvantage of losing competitiveness. And also, because right now, if you have a look at the, let's say, the major players in Germany, it's not an SME, but companies like Bosch automotive industry, Siemens, ABB, etc. The major ones No, regular Yeah, the bigger ones also, that they advertise or communicate much clearer strategy. And this leads, of course, also to applicants, for students who just finished just graduate when looking for a job. So two more look towards these bigger players. Because they say, Okay, we have a long term vision, we have departments that are familiar with working long term, that are not only looking towards up to half a benefit within the next three months. And of course, then people tend to go to these companies, preferably. So to answer this question, yes or no, if enterprises do account for these policies, this would also give them a benefit in what is often called the War for talents and so on. But, but this is a thinking that is not very common. In most of the companies. Most of the companies really go forward. If it's not profitable for me in the short term, I won't do it. And then of course, I lose some, competitiveness.

Interviewer

Yeah,. I found this also, within the case studies that really show exactly what you're saying it's that the federal policy government in directives are considered second, if at all considered, it's mostly about what’s happening in the area, and how are competitive advantages can be achieved and met and maintained at the same time. Because with the transformation is always continually changing, and it's okay, we can maybe transform right now. But the updates the maintenance, is it feasible? And is it possible as well, especially with research projects with the government, you might have to put something in once you have the funding with the government, but is it maintained afterwards?

Respondent 7

Right. And some issues that are also critical are that there are so many other topics that need to be handled that often there's just not the manpower available, not even for, for robbing distribution afterwards, after the research project has been finished. But sometimes there is not even enough capacity available to appropriately staff the project in the first place. Yeah, that's always. So it could also be the case that a company says, okay, we want to participate, we want to build this, but then after half a year, they see, okay, there are other pressing issues, we see that? Well, the other pressing issue, we might have expected short term profit, the other we don't. So let's just drop the other stuff. So all the basic work that has been done in the other project is then lost again. So everything needs to be started with and small, and this is also a big thing with it, especially with the smaller companies or with those more traditionally oriented companies.

Interviewer

And so what would you say then, in your opinion, is there a way that policymakers can help support these challenges? And especially when considering in relation to adopting and implementing industry 4.0 within the policies? So are there certain things that the government can do with maybe funding or, again, research and development, education to help encourage and maintain keep that the adoption that's already been done?

Respondent 7

Yeah, on that respect, I will differentiate between is there enough money for funding? If there is, then let's assume there is enough, we don't have any money problems, then the other assumption we would need to do is, do we have enough people who are willing to adopt this mindset? Who would be willing to flip the switch basically, from what has been done traditionally in hardware really requires now stronger a bigger part of software? So, this transformation from or this digitalization, of course, is now requiring more. And say, might be a little bit harsh to say, but it requires a different kind of thinking that says that, in the future, the products are not coming with that, or didn't need that little bit of software, that is just required to make the product one, but it really needs to be different data services are awesome, more added value to the traditional products. And when you require or when you want to push people towards this thinking you would always hate this. We haven't done this before, why should we change, it has always worked like this. So, and this cannot be changed by government. This is a really a thinking in terms of in the hands of the people. So what my personal worries are really that even if the government would now say only solutions that will fit into the industry influential portfolio will now be founded from now on I'm quite sure that a lot of companies would rather go out of business because they would not be able to adapt quickly enough in the thinking their mindsets and how they position themselves and their sense themselves, or how they would approach that such software solutions.

Interviewer

This is because they completely lacked the ability and the focus on the area of which to develop, there's no guidance.

Respondent 7

So right now, of course, they're all running software products, also traditional companies. Of course, this is not impossible. But this is more centered around the thought of, we just develop that necessary part of software that we need to make our hardware run, like mechatronic systems. So for example, if the system requires some PLC programming, then the PLC is being programmed, so that, for example, a robot conveyor belt, or whatever is being acted on. So, they have sensors, you have actors, and then we'll just connect them to your PLC program. And then those people say, okay, now I'm finished with my work done. And when you come out with requirements from industry 4.0 let's say, okay, we want to have abilities, interoperability, we want to have reusability of the Big Data building blocks. So, you quite often hear as a

response, that's not my responsibility. No one pays me for that, my job is to make the machine run and if it's running, I'm ready. If you don't pay me for that, if it's just the government law that I need to fulfill, as long as you don't pay me, I won't do it. Yeah. And this is quite often something that you hear. So even if the policies or if the funding are immensely strict, you will always encounter these types of mindsets and these hinder industry for quite a while.

Interviewer

That's a really interesting perspective that you provide, because with some other experts that I've interviewed with, one of the similar challenges that were brought up is, is what do you actually need to operate with industry 4.0, what systems and applications are actually needed? And, and again, with the guidance, some of them mentioned that you find a lot of organizations or enterprises that want to just say, I want a cloud, I want a cloud system, or I want a data warehouse. And they, hear buzzwords, and they see that it produces value in the others. So, they just want, well, what, how do you want to design how, what type of one do you want? And it, not really possible to identify for them. What's, what would actually produce value, it's just more of we see this is a list is the type of things we want. And just put it in, and it might not actually produce a lot of value for some of them because especially SMEs, some of them are on a lot smaller scale. So, does it actually produce value? Like when you see the later question, I asked you about different stages of digitalization. Like stage four, stage five that's, that's the best level you can get. But does it make sense for all SMEs? Right? Some of them the cost is too high to get between the levels, you'll never make back the profitability. For some of them they're on the more traditional sense.

Respondent 7

I've heard this also in the past that you just say okay, let's use some cloud solutions let's make a corporate data lake etc. Eventually, such a debtless I'm quite convinced that they will pay off especially when you need to find a why has something happened. If you go for use cases such as really collaborative, the eyelid masters also which are also propagated in the fields of via explanations as a data space and if you want to have something like a federated look up or federated index or something, where is something why Has something happened, etc.? To answer these questions, you need to do is a lot of preparations for sometimes thee years. So, you have some 3,4,5 years where you do not get any return on invest. But in the end, it will pay off. The point is that most of the companies are not willing to go this way. No, they do not want to wait five years until they get a return on invest. But the policies, of course, aimed at such a long-term change in the data and the data pipelines. So, right now, you would have two approaches, I would say either follow them, do some small steps that work towards this data continuity chain. Which is right a nicely described in a nice icy white paper on semantic interoperability that really shows what kind of data quality needs to be reached, to enable such a continuous value chain. But on the other hand, many companies say okay, and I don't see a value for their SSN, as long as the machine is running, and I get my data out of it. And that has a sense of value. I can go work. Okay. And I am a little bit worried also that this still remaining, or unfortunately, the HR mindset get propagated. Short term profit thinking would eventually slow down the

adoption of the industry 4.0 principles. And we're talking only of machine data here. Of course, it's not personal data and not high security data always. Yeah, this is operation. So yeah, it's really machine operations. That's, what this is, this is something that I'm a little bit worried about.

Interviewer

Okay, that's, interesting. I haven't heard that yet. That's, something that's definitely worth looking into.

Respondent 7

I mean, it really depends on who you talk to. If you talk to experts from Bosch, from Siemens, from wherever in this field, for example, Siemens has been in the field of digitalization digital factory for over 20 years now, more than 20 years ago, Siemens always was on OK, we only do that kind of software that our customers want, or it doesn't do our customers need to make our products wrong. Now, Siemens is one of the biggest software vendors in the world. So there has been quite a change. And there was also with the different services that accompany the different products. For example, in Siemen’s healthcare, there was always the need for how to optimize something like maintenance for cathode ray tubes, for example. So, if you have a maintenance interval, then you will not be able to work with your, diagnostic tools for a day or so. So, it would, of course, cost a lot of money. And so, Siemens was very early, aware of the need for continuous data for data quality, etc., also the digital factory environment. And that's why they’ve been working in that field for a long. Others are now slowly discovering these needs. Unfortunately, the others who now discovered what is actually necessary, are not willing to go back and say, okay, we have seen from the others what is necessary, let's just follow them. But they always go for, do we really need this in our environment during this? Why do we need this? Let's just make lots of meetings centered around all these questions that are actually already been solved elsewhere. And just against low style, the progress or not, if you talk to more software, and a few companies, where you have many, more software developers or software processes established, then you would, of course get more Pro software arguments. And as I see it, come from my environment where you have more hardware thinking in the hands of the people, then you would get lots of meetings which allowed simple questions where you can say, where you discuss for hours Do we really need to get back on this level, so if you talk to people from a software company, they say, okay, we just we don't talk about it. We know it's necessary. Don't talk about it. In other companies, they use a lot of tracks by centering around such simple questions.

Interviewer

Actually, so maybe in relation to some of what you already mentioned, are there challenges and how can policymakers be addressing them. Are there any particular challenges that you noticed that in the field of industry, 4.0 adoption in SMEs, the machine tool sector.

Respondent 7

Yeah, as I said, it's the continuous digitalization, but it's the continuous is the biggest one. So that you especially create a mindset, why, for example, do you need to that just structure your data block on the PLC program? In that way, and not the other way? around as I said, that there needs to be an awareness for other people should use my data. Yeah, right. Now, the mindset is, as I said, it's like, I'm done with my work. It's run, functional requirement fulfilled, might change it, if it's working out that way. Right. And what I've also heard, in some cases, is that if I provided the data in a way that is reusable by others, then I have the work. And the thoughts and the others have the benefit. Yeah. And I do not want to enable them to make profit when I don't have anything from it. So, it's this thinking in terms of change, that the downstream elements of the downstream parties would have a benefit from what the upstream parties do.

Interviewer

So, you would probably be more in favor of the German approach of Plattform Industrie 4.0, with sharing the successes and challenges between or not fully sharing, but I would say more so as an extent than in, other markets, that there's more sharing of the different challenges and successes, which different actors are facing.

Respondent 7

Yes, of course, there are always some companies or some proprietary stuff, some intellectual property so that they just don't want to share, of course, there's always the case. And there needs to be solutions that support this as well. This is something like, I will say, for example, Deus Ex, etc. They all foster this as well, if they advocate on the same hand data sharing, but control data sharing, but they still advocate for this continuity of data. And I think this is crucial for the success of industry policy.

Interviewer

Okay. And I'd asked you about what can be done in policy, but you've kind of already touched on that in the on the previous section, but you talked about XXXX and how one of their successes is that they are already looking ahead with adoption, which is the challenges that you're saying most companies are facing? Are there any other successes? Maybe because as soon as is larger enterprise, is there any in the SME sector that you think where there's successes being seen and in the adoption process within Germany?

Respondent 7

I'm afraid what I can say here is it's always been a big question mark. So you need to verify Yeah, but of course there are in the to machine sector, companies like dmg Mori also for example, that we have, when you look at the SPS price also, this this fair that is taking place annually right. Analysis called Smart processes. So, the famous ones called SPS PLC, guys, okay. And then there are exhibits by really major automation companies and in different fields of industry for SEO. And of course, as I said dmg Mori in the true machine sector is one that comes to my mind or for example, lead to automation also once showed on

in the trade fair, pretty cool use case of continuous use of assets, administration shall be used to conceal concepts. Even if it was just for the fair, it still gets into conception. And so, these are not really small but medium enterprises, at least number is more as dmg mori is like, but also something that traditions, truth comes to my mind. And, of course, there are for some niches, there are some small enterprises that have some interesting approaches for example, connecting machines also having some fancy UI, I would say to make machine connectivity easier. So, for example, the OPC UA sector, also.

Interviewer

So, then I would ask you, how would you assess the integration the IT department with industry 4.0 and German companies?

Respondent 7

It depends, I mean, I have no insight into that. Of course, on the SMEs, their IT departments what I see in our field is that there are of course, some external. Yeah, like consultancies that are being asked or that. Yeah, where projects are done, like with companies, or outbreaks, Accenture, Deloitte and consulting companies? The company PwC and, of course, they're always hired to investigate internal processes, and to develop some evolutionary steps. And the IT companies, the IT departments, sometimes they are still centered around, we have a certain product that you need to run and maintain. Like, we have the workshop, we have an SAP installation, we have company wide SAP installation, we have engineering installations, engineering work, through chains, etc. So that is IT departments are focusing on keeping these two chains run. But they are not. Not really focusing on bridging the gaps between the two chains. I see.

Interviewer

Okay, so there’s not really any integration going on. It's more kept quite traditional, in the sense of an IT department.

Respondent 7

Yes, I would say that. It's not all, but, of course, not enough, or also not much awareness. So, what I've also witnessed is that there are two tools that one person needs to work with and needs to transfer data from one another. And then because there is no true integration or no connection, people don't just for a copy paste of the values from one form to the other. So even that is sometimes done because IT department does not see the need for investing the money for the true connection.

Interviewer

Yeah, that something that happens a lot, people copy, you'll get a piece of information in one thing, you'll have to put it into Excel and just to bring it over the systems are not interoperable at all.

Respondent 7

Right, so as long as Microsoft Office 365 is considered the backbone of, competent IT, then it's always a little difficult to make some industry for so many integrations wicker

Interviewer

does the collection of data on how customers utilize products and how the data is utilized to improve the product commonly practice, particularly in SMEs? So, is the data being gathered? And is it used to actually improved the product after? So, for services or product development?

Respondent 7

I would say, yes. As from our company, and I can say that is the beta from their customers is gathered is evaluated, and there are, of course, improvements to the products being developed. And this is definitely also done by others as well. And otherwise, it wouldn't make sense to have at least some kind of monitoring, it depends on of course, if it's a product that needs to monitor a personal data or if it's a product that just monitors machine data, so, it's like something like vibration analysis or something like this then they would not immediately improve the product or the software that is measuring for example, where or the migration, but you would use this data to prove the machine that's been measured or monitored. But of course, from a software solution themselves they would also use this use backward process.

Interviewer

Then for the question of how does the organizational or and or the organizational and strategic aspect So, vertical integration influence industry 4.0 transformation

Respondent 7

I mean right now the thinking is still in terms of horizontal vertical, in terms of automation part. Industry consumer, and how are you aware of the concept of automation pyramid? Not the pyramid in general, because this is the lowest level of IT integration, we have the shop floor and then we have PLC MDS were pieces stem supply chain management and so on.

Interviewer

Yeah, the ERP system.

Respondent 7

Right. And so, there's always this vertical thinking of we go from the LP down to the shop floor. Okay, yeah. And horizontal integration is then connecting the different the hospital is on the upper level. This is still traditional way of thinking and its very common edits. It's also a good metaphor in the industry for

SEO field, there's more and more something like a peer-to-peer network because the distributed computing facilities edge computing etc. It's not so strict the pair of with anymore. It's more and there's this. You may know by Professor Heiser, it was introduced a couple of years ago that it was more like an hourglass as somebody who watch the clock that he knows for measure time, this was a metaphor that invented or introduced a couple of years ago. And this cost some little bit of a revolution that we applaud because this was something completely different than what has been introduced for decades. But in my opinion, this is the thinking that needs to be adopted more and more in the future. So how horizontal and vertical integration right here is especially the vertical integration is not so much anymore. Going down from want to happen, your PII that needs to be eroded over the years etc. But with an edge computing facility, you can just say Okay, I need to connect, is there for example, an OPC ua connector in my MP? For example? Why not just connected directly to the sensor?

Interviewer

just get it directly.

Respondent 7

Right. So, what is much more important is, again, the continuity of the data structures, the data continuity, so that you have something like a lot less transformation from one step to the other. Okay, let your only enrich information but not lose something on the way to the consumer.

Interviewer

So, with what you're saying, there's actually kind of ties into the seventh question that I have, which is, is there a value in enterprise systems that support departments or like ERP systems? And do you think that they should play a more crucial role in industry 4.0 adoption?

Respondent 7

To be honest, I was not quite sure what you mean by this question.

Interviewer

So, like CRM systems, so customer relation, you can even have the ESS systems for executives. So just the systems that are that are installed that support the operations for knowing how many items are in our in the facility. So, these types of systems are the sale system. So really integrating, like the sales support systems with the menu for the service systems? Do you think that there's more valuing in really connecting them?

Respondent 7

So, you have some more specific functions assigned? Yeah. Yes, I would say if you if you break it down from what the business processes are, and which systems are required to fulfill the process and process steps, and which data are necessary to let's say, monitor whether its data has been fulfilled properly or not, so I would say yes.

Interviewer

then that would tie to the question I have based on SIMMI 4.0 Do you know of SIMMI 4.0 it's a maturity model, it was produced by TU Dresden in for evaluating the IT and application landscapes within industry 4.0 adoption. My question was going to be is in your professional opinion, what level would you expect most companies which are SMEs in Germany to be on and then also what level would you believe the federal government would expect most companies to be on currently?

Respondent 7

I would still say that, from that point of view, probably the majority is still on level two, level two to there. You might have some continuous automatic data communication across departments with a company if they say, okay, we want to build a solution together. Of course, this is possible. But I will say that in the majority of the other companies still send around exercise, but yeah. And, and but I would call assumption. knew many years ago, there were also some automated work order generations based on incoming orders.

Interviewer

Yeah. The I would say the larger companies are already above the SMEs on that level. Right. And so that's the level you would indicate them on and for what would what level would you in your, in your opinion, would be the level which the federal government would currently expect, and want most companies to be on? Particularly in regard to some of the policies that you've read on industry 4.0 so with what with what they currently publish in the policies, what level would that indicate as what they want to have currently achieved?

Respondent 7

Okay, because this is one prominent example. Because it was respectful. It's very friendly. And like, some it's not. And so on the European dispatch, she has defined these nine initial user data spaces, strategic data spaces like industry for SEO, mobility, healthcare, agriculture, public sector, and so on. Okay. And for the and this has been broken down across to the national strategies, journal data strategy, etc. And since most companies that are required to make this run, are, of course, very distributed from logistics, I'm talking about the biggest priority from logistics from public transportation providers, etc. Because there are also disparate and are not controllable. Then in March, the German Chancellor has issue, the demand with the October of this year, she wants to have the data space fully ready on operational. So just to give an impression of where the companies are currently on and what the policy actually wants. So of course, there

are now some companies engaging in that, because probably they would say, okay, we fulfill the expectations of the ministry. So, what we want to fulfill that, and they push a lot of efforts into reaching this higher levels of digitalization. But then, again, these problems of do we have enough skilled capacities, staffing? How can we integrate this into health into our daily business, etc. So, this is quite a challenge between the expectation and the current situation. So, I would say they want to happen on stage four to five. Yeah. But as I said, some are on stage too. And then they have some quite some way to go, especially if they want to do within this year. That's quite a challenge.

Interviewer

It's very ambitious.

Respondent 7

Definitely. But if you want to have a look at that, you should move on to some of the hundreds, also, for data space mobility in this example.

Interviewer

Of course, it sounds really interesting, I will look into that. Okay, so the question I have is the utilization of service-oriented cloud applications and big data applications can provide companies with a competitive advantage. However, privacy and data security is a major concern of the federal government. So, what is your, opinion on the matter of digital privacy? And how can SMEs continue with the adoption of industry 4.0. Well, attaining the position which the federal government wants for data security. Would you say that data security is a challenge for most SMEs, particularly because of federal policy? And because I know that this is a really big topic in Germany. And how does it really impact the adoption of I4.0?

Respondent 7

It depends on which level again; you are looking at data privacy. If it's of course referring to personal data, then well, we all have to face the same issues. The question is just is it more or less implemented in a digitalized way or not? So again, this refers to an on-stage module. Because in some cases, for personal data, I would say some people have some Excel sheets that they just follow in filling out or in checking whether we have personal data welcome. Another issue is it If you have here, because it's service-oriented cloud applications, if you have something like condition monitoring tools, for example, that you sell to a customer and the customer extend to a cloud service, and then somebody else might want to make a business model based on this monitor. I know that, for example, in terms of cloud interaction, cloud infrastructure set up, etc. This has been dealt with as an issue in in standardization, also. But the big thing in terms of privacy is that many, I would not say most, but at least many customers of machines were up, the actual operators of the machines are worried about sending the machine monitoring data to external clouds and try to really use public to use cloud services for analyzing from monetary, the locally generated data,

because the thought is like, if somebody else could monitor and analyze my machine data, and this is something like what happened in terms of temperature, rotational speeds of tools, etc., then one might be able to draw conclusions how I produce my products and this is basically something that, in many cases needs to be solved in advance before you can set up in such solutions. So, you need to have answers to that, in terms of is it ready safeguard it, Can nobody else?

Interviewer

Yeah, actually you have certain application systems like, that some companies are allowing to be run on different machine tool companies. There are some machine tool companies where they're allowing the running so they can provide service to machine tool companies that were not manufactured by their company. So, would this be a challenge for the machine tool sector? Because you could theoretically, the company that's, gathering the data to provide services for a company for a machine that's knows what was sold by different company, they can harvest that information?

Respondent 7

Yes, I mean, again, this is this is twofold. This is a challenge in terms of finding the right business models. Because this is one standard use case. For example, if you go again to the platform industry, first your use cases. There have also been some investigations on one vendor sells the machine, the other vendor sells and some sets of analytical software service machine. What are the contractual interrelations between these parties? And what are the government data flows? What do they imply? So, there's, of course, a lot of contractual agreement that needs to be done. And this is one thing, and this is also a challenge in terms of making such value chains more transparent.

Interviewer

If it's transparent, it doesn't matter if the, if another company is able to pull the information,

Respondent 7

right. And, of course, then you also need some stuff that's able to maintain such solutions that keep up such privacy, data privacy, things like to have somebody that is scaled in terms of authentication solutions, like you have to have some certificate management and so on and so on. So, this is important of course requirements to staffing. And one thing that is also issue is coming, in my opinion with the goal of trustworthy AI, explain ability and this is coming from the European Commission.

Interviewer

Yeah, they're pushing AI right now

Respondent 7

Right. And they are not only pushing AI cells as a discipline, but they're also pushing this aspect of trustworthy AI. Yeah. And this means continuous end to end expandability in the worst case. So that means, for example, a couple of years ago, there was a very bad accident in one plant in Newcastle, where a worker got killed by a robot. And because of that, even though there was a proper program programming to place the robot, so it was open. But for some, some reason the safeguarding did not work, and the worker was in the cell. And so, the robot started moving and killed the book. So, if something like this happens, and this would have been some kind of AI based solution, yeah. Then it was not like there was some other issue or some other problem. But if there would be some AI based solution in both chain of where is the data gathered in the field from the sensor? And what is the decision made based on this data, and there would be some harm to the person. Then, of course, in the end, trustworthy AI says, okay, now we want to have a justiciable explanation where the lawyer can work with. And in order to reach these explanations that can be used for court for compositions, the entire chain needs to become transparent. So eventually, there is no such thing of data privacy because of business interests more in place. Or at least it doesn't play a role anymore. Because the, from a legal perspective, I mean, I'm not a lawyer, but from what I gather from the strategies, is that from a legal perspective, that legal interest would in that case, overrule the business interest. Yep. So even if the company say, hey, we have data privacy rules, and we have security rules, and you're not allowed to see that, etc., if somebody is being harmed, a company must become transparent in that case. Now, there's not and this definitely poses a lot of pros to any company in this chain. Because as long as companies bring intellectual property into these changed chains, they are interested in becoming transparent.

Interviewer

Now, they're forced to be transparent at that point.

Respondent 7

So, let's see, I would say it's quite a challenge in that respect to adopt it.

Interviewer

Yeah, because he can put, the company at risk with the transparency at that point, with having an investigation put through. So, I have one final question. And it's a combination of two. So, can the current policy surrounding industry 4.0 be improved? And if so, how? And do you have any input and suggestions on how the government can support for their support the advancement of industry 4.0 within Germany?

Respondent 7

I mean, the as I said, the big issue is making things interoperable. So, this is the major goal of industry because you always put it like this, to make the different partners systems along the value chain. In terms of machine-to-machine interoperability. For example, this does not mean that you put the human out of the

loop. But in many cases, this machine-to-machine adoptability, or working towards this machine-to-machine interoperability implies at least to, to some of the decision makers, we need to heavily invest in redesigning our interfaces, etc. And, of course, this is again, a short term affords but no short-term profit. Yep. And it's quite difficult to convince decision makers to risk this investment to have some let me let me put it like these making systems requires understanding the semantics and then linking the semantics. semantics is usually considered an additional form that requires a lot of standardization. Okay, and does not provide me the process or the dependency. In the digitalization environment, unfortunately, this is quite often my thinking. I'd say at least in those circles, where they are looking in a more productive and agile way. Creating end-to-end interoperable applications of value chain is not something my opinion that can be solved in a product thinking way. And by product thinking, I mean, like we have this particular problem, let's create a solution for it. And then we're done. Instead, you need to synchronize and harmonize across many solutions. And then each of these parties, let's say, all come raise the question, what benefit do I particularly have for my use case, because I only want to add a product or solution for my use case, I'm not interested in the others. Again, machine to machine interoperability requires exactly this harmonization across different use cases. So, reaching this or working towards this is more investment in long term sustainability of your platform architecture or system architecture.

Interviewer

No, yeah, you're right, this is actually something currently in the 2030 vision for industry 4.0 by Plattform Industrie 4.0, and so, they have three main points. So, it's autonomy, sustainability, and interoperability. And within the autonomy section, the main focus of the policies is how to connect the machines and the systems not only now within Germany, but across Germany, within Europe, and even with global partners. This is really so it shows that they are expecting, you know, going back to the stages that they want companies to be within that at least that third or fourth stage. So again, it shows you the big gap between the policy in the actual spot, and where semantics of the AI systems for communicating so that they can work on autonomously and, across departments. This really is the focus that's being pushed.

Respondent 7

Right. And what's another topic, at least that comes into play here is do you want to have machine as humans in the loop or not? And even though, machine interoperability is the focus, in many, many use cases, you need to have a human person as a final decision maker.

Interviewer

So, you have this on trains that are autonomous, there's still a conductor on the train to make a last-minute decision.

Respondent 7

Right. So, this, means when you look at the AI field, that the explanations that need to be raised by an AI system are provided by an AI system for institutional decisions, need to be prepared in a way that, of course, it is based on machine semantic interoperability. But it's being presented to the user in a way that he recognizes it as another important explanation, where he can immediately see why this explanation has been generated. So, even though you need to have end-to-end machine-to-machine mobility, for keeping up lossless communication, and we need to enrich this data on different levels and stages, to provide a really comprehensive explanation of the bond to the user, and the final decision, and this is definitely something where many, right now working analytical solutions, etc. slack to adopt this, this raises a lot of questions or a lot of reports. How do I just define performance? Yeah, and then my, hope would be that there are some, that would be some maybe showcases more or ideal examples that really convincingly show the benefit of seeing these solutions. I mean, it's always difficult to come up with such examples, because you need to have people who are willing to take this endeavor, of course, in the first place. There are not too many. And then it's always, of course, hard to extrapolate. Because if you do such complicated calculations or simulations right now, you just don't know what's once you get some monetization in four or five years, no such scenarios are required to convince today's decision makers. So, I would be hoping that the politics also combined such examples essence underpinnings to, their most basic orders, because demand such submissions is one thing and pushing companies or technical solutions into distractions, also nothing but at the same time, provide them with convincing explanations and why it's really necessary. Oh, why it's really useful to do this. It's another thing. And I think that politics is not always going into the right direction. It's not just my gut feeling there. I mean, there are scenarios there are always different lobby organizations or organizations like Bitcoin, that provides such samples etc. But in my opinion, it's always like early just issue some act, but they have not fully considered how this would actually be implementable. What to motivate people to look for mentors, I mean, if you look at the chairman data strategy, except for the stuff in the public sector, or the healthcare which this one gives the creeps, but the technical environment is well written and therefore have a lot of, I would say, wise aspects to pursue. The wisdom behind these words, I would say, is really something for the experts. So, the data strategy itself is not adopted. Whether you can give to a decision by the business. And I think there needs to be some, very simple to grasp explanations or scenarios that are also officially mandated by either government, basically, the basic of the government as the process, of course, we have this law, and now, organization, maybe investigate, provide, etc. And then the process is, it's quite slow or quite competitive. That's okay. Of course, there needs to be different opinions. But I think that the motivation for industry 4.0 should also be strongly tied to why we actually want to use one to it to put a certain act into action.

Interviewer

I understand it completely. What you're saying is these points were brought up by others as well. I think the policy has been pushing, in some good directions in Germany, one really great thing is that when they are developing the policy for industry 4.0, they have expert opinions. They're consulting companies, they're consulting the unions, they're consulting, academics, whereas in other countries, they're not doing this as

much. And I think this is why even with industry 4.0, you see Germany taking a global leadership role. They help the Chinese draft their industry 4.0 policy, and it was mostly built off of the German one, but even in Indonesia, they had developed it off the German one as well. So I think the approach that Germany has adopted and taken, it clearly has to have shown some results for other companies to follow suit, I think.

Respondent 7

I mean, in Germany, of course, we have also the lot of standardization roadmaps that also illustrate why certain aspects need to be pursued or somehow was not summarization, artificial intelligence roadmap and so on. But what I don't see right now from the German government as well, something like the Commission has issued on their websites for the different strategies for the different accents on if you go to the European website, they have something like two- or three-pages management, executive summaries, illustrated in some island with some nice graphics and so on. That are very condensed, summing up, why they have issued a certain data governance, for example.

Interviewer

It's more transparent.

Respondent 7

Yes, it's, and it's easier to grasp. But if you take, for example, the chairman data strategy. I mean, right now we need to be happy that they have something. The issue for the Gemini spreadsheet as well as summaries like for example, is the data strategy. It's a document with 100 120 pages or so. And many of the different features or functionalities that are pursued are buried somewhere in 10, point, fonts in some tables, etc. So nobody would really go through the entire document. No, yeah. So it's very difficult to convince people if they are not familiar with it. With everything there is so many people who are now presented the document and say, Okay, what can I expect to make a slide? Make sure, etc. And this is something, in my opinion that just the German government should look at different acts provides such a summary. Why is something like data privacy? Why is reducing of vendor lock in? Why is reducing of transparency across the entire value chain?

Interviewer

No, yeah, you're completely right. Because I had to do a policy analysis to really identify what the federal government wants to achieve for my research, and I went back and looked at all the, German policy and when you really look at it compared to an EU policy, it's all over the place. It's not very coherent, and structured, I find in the sense of really indicating why they made a decision. And within that decision, what they really want to achieve. And I think this is kind of difficult for companies that want to maybe even do research and get research and development funds. Because you're not really sure, well, within this field,

what is it what is expected of our enterprise. And I think that, right, if you if you can identify what the federal government wants, you can then develop projects, and seek funding around it.

Respondent 7

Right. And I'm also quite sure that not many companies or people in the companies are willing to go over hundreds of pages of usable text. Because, first of all it doesn't read very fancy. It's definitely not fun to the limit text. And then drawing the right conclusions from this literal text is also quite a challenge. So how can you be sure that you have drawn the right conclusion from the text?

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