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Review Article

Industry 4.0: Understanding Needs and Challenges of Technical Textiles Industry

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Abstract

Industry 4.0 will influence the way how organizations operate and create value as information communication technologies are applied on the manufacturing industry. Organizations need to adapt to benefit from the value creation potential behind this change. A methodology is to be developed that examines the organizations capabilities in digital technology aiming at building a value proposition in Industry 4.0. Strategies used to source digital capabilities in terms of human resources need to be provided. In order to address this challenge, a methodology was designed to evaluate the industry's current capabilities in digital technologies. Competencies required were derived while considering market and technological environment. Based on the gap of required and existing capabilities, sourcing strategies and priorities were given. Based on the analytics, recommendations were given regarding hiring an employee to extend the industry's competencies in data analytics that had been prior little developed. A path forward towards integration of Industry 4.0 in the technical textiles industry is provided in this paper.

Keywords: Competency Analysis; Data Analytics; Digital Transformation; Employee Assessment; Industry 4.0

Introduction

Digital technology is about to significantly change the manufacturing industry while making it more efficient and productive. Major innovations in digital technology, emerging or mature, such as advanced robotics, sophisticated sensors and cloud computing are going to be embedded into a global value chain. Utilizing these technologies on the shop floor, smart machines are enabled to exchange information independently and initiate activities mutually among each other. By building a digital thread (a virtual representation of the part) between all stakeholders of the value chain, product development is accelerated because the latest model of design is synchronized. In this so called fourth industrial revolution, manpower is not being replaced by machines as humans are enabled to make better data-driven decisions utilizing the data of a smart factory. These technological advances results in various value drivers that are indicatively quantified in (Figure 1).

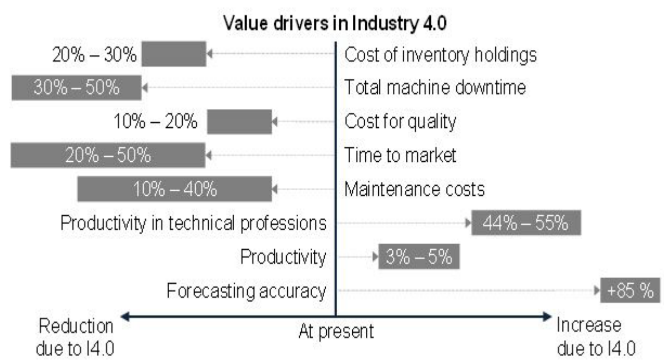

Figure 1: Overview of Indicative Value Drivers for Industry 4.0 on Manufacturing Sector.

As an example, for the aerospace sector, given that project lead times from conceptual design of an airplane until final delivery are more than 10 years, a reduction of time-to-market in product development of 20 % - 50 % would have a tremendous effect on the aviation industry. Benefiting from the advances of technologies, further cost reductions per aircraft is feasible. By utilizing a more flexible and efficient mass customization, European aircraft manufacturers are enabled to maintain competitiveness in a challenging market environment. The logical question that arises is what organizations need to do to benefit from the value creation potential of the fourth industrial revolution.

The beginning of industrialization (1st industrial revolution) in 1750s was driven by advances in mechanization, and the use of water and steam power which enable the realization of the steam engine. Although a first substitution of labour by capital, process, stability and speed was initiated, the population increased significantly and was provided with new means of transportation (railway, steamship) and clothing [1]. The 2nd industrial revolution (Fordism and Taylorism) began with the introduction of mass production, electricity and assembly lines. At the same time, combustion engines and electric drives were developed [2]. The radical innovations of the 1970s in automation technology of products and production technology mark the beginning of the third industrial revolution. These advances were possible by using latest Programmable Logic Controllers (PLC) and computers [2]. A timeline of the past industrial revolutions as described is shown in (Figure 2) below.

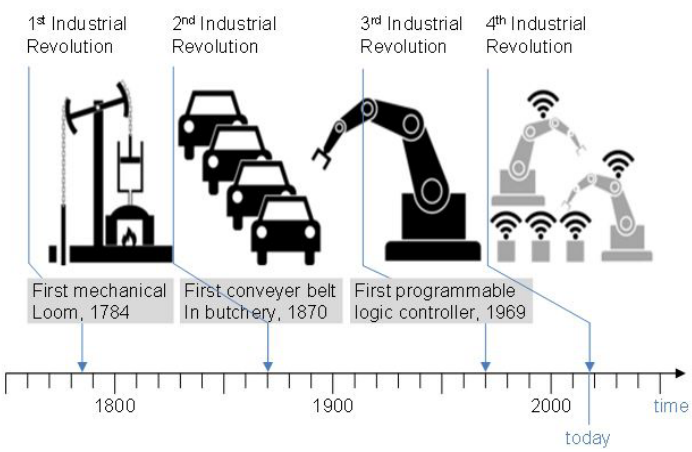

Figure 2: Timeline of Industrial Revolutions.

The latest technology shift towards digitalization is marking the next industrial revolution. In Industry 4.0, the manufacturing industry is digitalized by using Cyber-Physical Systems (CPS) as discussed in further detail in the following sections.

It is due to advances in internet, communication technology and low-cost sensors yielding better energy efficiency that these technologies can be integrated within various parts of the product and its equipment generating huge amounts of data. Cyber Physical Systems have integrated computational and physical capabilities allowing new forms of interaction with humans [3]. Using these CPS improves connectivity and communication which enables condition monitoring, systems and structural health monitoring, remote diagnostics and control, as well as tracking and tracing [4]. These CPS's create a vast amount of data that requires processing, management and storage. This can be realized by centralized data storages units that are required for cloud computing and big data analytics.

Summarizing, a concise definition of Industry 4.0 is provided by McKinsey & Company. 'Industry 4.0' is defined as the "Digitalization of the manufacturing sector, with embedded sensors in virtually all product components and manufacturing equipment, ubiquitous cyber physical systems, and analysis of relevant data." [5].

The Internet of Things (IoT) and Industry 4.0 related technologies are at the peak of Gartner's Hype Cycle. There are reasons supporting the flourishing of these trends. In fact, the sensors required for smart devices benefit from advances in the fields of microchips and connectivity. In 1965, an INTEL engineer in California, U.S, predicted that the "Computing power would dramatically increase in power and decrease in relative costs at an exponential pace" [6-10]. Furthermore, it was predicted that the amount of transistors on a microchip would double every 18 months.

The exponential decrease in maturing of digital technologies is shown in (Figure 3). With sensor costs below 1 €, machines and products are getting equipped with a vast number of sensors used for measuring key parameters likes temperature or vibrations. Further advances in connectivity technologies also decrease energy consumption of sensors. Depending on its use, various connectivity networks are feasible. Key aspects are the range, data rate, power consumption, frequency of data transfer and security when choosing a communication system for the respective sensor. [11].

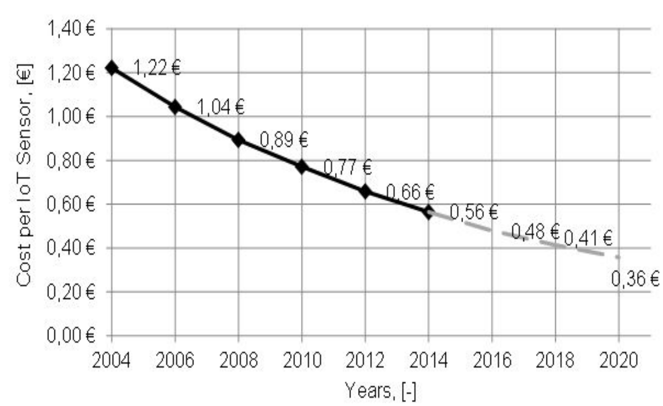

Figure 3: Trends for Cost of IoT Sensors from 2004- 2020.

The capabilities of such Smart Connected Products (SCP) can be grouped in four stages of automation i.e. monitoring, control, optimization and autonomy [12]. Each capability has value on its own but also sets the stage for the next one. The first level enables the monitoring of the product's condition, the external environment and the operation and usage of sensors and external data sources. In step two, the control level is introduced. The product's software or the product's cloud software enables controlling of product's functions. By using the product's monitoring and control capabilities, software algorithms enable optimization of products operations. Product performance is enhanced; utilization, output and efficiency improve significantly. Real-time monitoring of the product's conditions offers development teams to optimize their service by applying predictive diagnostics and repair remotely. Predictive diagnostics are possible due to the processing of large data sets that also enable other fields of application. Unleashing the full potential of smart connected products, autonomy combines the three prior mentioned steps. As they can learn about their environment, the products can run operations autonomously and coordinate own operations with other products and systems. Furthermore, the interaction possibilities, as well as the value of a network increase exponentially if a new product connects to it. At this stage, autonomous product enhancements and personalization are feasible including self-diagnosis and services. Consequently, as the need for human interaction declines, the operator will only watch over fleets instead of individual units. The cumulative addition of the four stages is illustrated in (Figure 4).

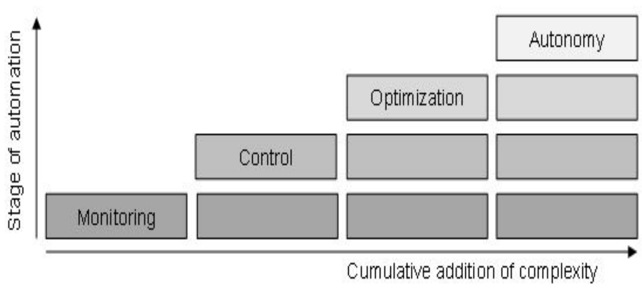

Figure 4: Stages of Automation for Smart Connected Products.

Industry 4.0 and Smart Manufacturing

Industry 4.0 is a specialization of the Internet of Things and Services [13]. The term "Industrie 4.0" was formed by the German government initiative "New high-tech strategy", whose aim is to support Germany's industry towards leadership in innovation. Within the United States, a similar initiative is launched and is called "Smart Manufacturing" and, like Industry 4.0, the main issue is "Networked machines (that) fully automate and optimize production" [14]. While the US initiative is data centric, the German architecture is service orientated. At the beginning of this decade, Germany, as one of the leading countries in manufacturing and automation systems, had no dedicated strategy towards positioning its Small and Medium Enterprises (SME) as Cyber Physical Systems merged in the manufacturing environment. To meet this lack in strategy, they founded "Plattform 4.0". As a first step, the ministry of economics, and the ministry of education and research assigned to Acatech, an academy and network for science and engineering in Germany, to analyse and define Industry 4.0 and provide an implementation guideline for its industry [15]. (Figure 5) shows the four objectives of Industry 4.0 as outlined by the German government.

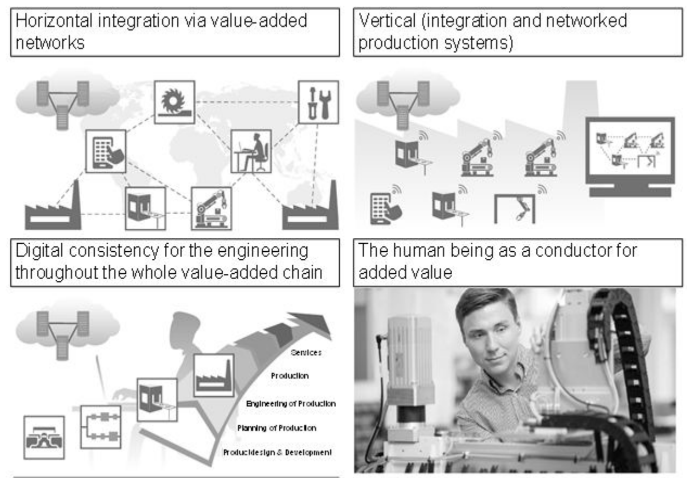

Figure 5: Four objectives of Industry 4.0.

Research Fields within the Industry 4.0 Concept are Defined as

- Standardization and reference architecture: This allows cross-company communication and integration into value chain networks
- Managing complex systems: Describing models for automation of professional activities and integration of digital and physical world
- Broadband infrastructure for the industry: This is required to enable data exchange in high volume, quality and speed.
- Safety and security: To ensure safety within the organization, data privacy and IT security
- Work organization and design: Demonstrating the implications for the human and employee as designer and decider in the Industry 4.0 environment
- Education and on-the-job training: Describing content and innovative concepts for education and professional development
- Regulatory framework: The objective is to provide a uniform, Europe-wide legal framework for Industry 4.0, e.g. protection of digital goods
- Resource efficiency: The responsible usage of all resources (human and financial as well as raw materials and supplies) is a success factor for future industrial manufacturing.

Although all research areas are necessary to investigate, the following will focus on the first research field "standardization and reference architecture", Reference Architecture Model Industry 4.0 (RAMI 4.0) as shown in (Figure 6), as the main outcome of the initiative [13]. RAMI 4.0 is a three-dimensional map describing a structural approach for Industry 4.0. Such architecture ensures that all stakeholders of Industry 4.0 can communicate with each other.

The design of the framework is based on Smart Grid Architecture Model, and extended to meet the requirements for Industry 4.0 [16]. This framework streamlines the interest of 15 industrial associations by developing a communication reference model. As previously mentioned this architecture model is service orientated and unifies all elements and IT components within a layer and lifecycle model. The process complexity is decreased due to the separation in smaller packages.

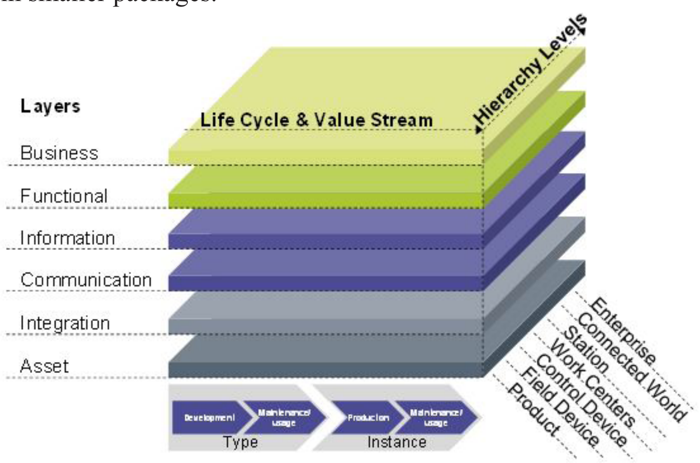

Figure 6: The Reference Architecture Model for Industry 4.0 (RAMI 4.0).

The first axis, hierarchy levels, maps the scope ranging from the smart product to the smart factory and the connected world. In the prior models of factory mapping, the product was not included. All participating stakeholders are connected and communicate with each other. The functions are distributed throughout the network.

The third axis illustrates the life cycle and value stream from development to after-sales services. The axis is separated in two parts, type and instance. Within type, development of the product and maintenance usage is described. The instance refers to the specific product with a serial number and associated data on production side, but also the information on facility management like usage, service, and maintenance instruction.

In more detail, the horizontal layers of the second axis are discussed. The layers are based on the norm IEC 62890 and extended by the asset layer that represents all physical objects in Industry 4.0. Each layer serves a specific purpose and communicates only with the next lower or higher layer or within the respective layer as show in (Figure 7).

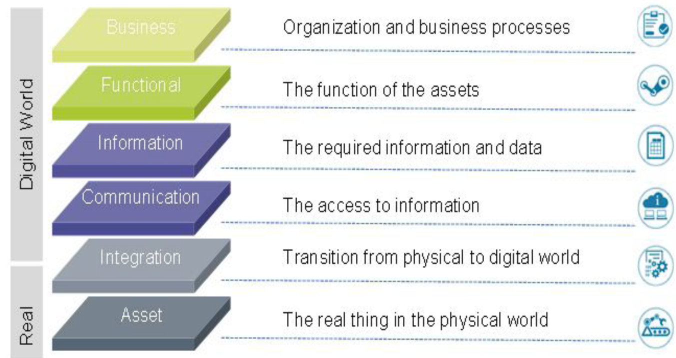

Figure 7: Horizontal Layers of RAMI 4.0.

Up top, the business layer controls the business processes within the context of Industry 4.0. The integrity of the functions within the value chain is secured as well as the modelling of the rules the (Industry 4.0) system. Different business processes are linked and events are received from other layers and moved forward. To enable this, the function layer organizes and supervises the services of the function layer, and defines legal affairs and the regulatory framework.

Within the functional layer, the rule and decision logic of RAMI 4.0 is positioned. A formal description of functions is defined as well as a modelling environment for services to support business processes are provided as a part of this layer. This layer also provides the platform for the horizontal integration of various functions and allows features like remote access. ERP systems and functions are typically positioned in this layer.

The information layer processes all data and events received from the integration layer via the communication layer. At this stage, functionality is provided to transfer raw data to information and make them available to others. Events can be pre-processed due to a framework e.g. aggregation of similar events, transformed and sent to the functional layer. In addition, this layer ensures the consistency and integrity of data are provided.

Building up on the integration layer, the communication layer standardizes the communication to the integration layer and offers services to control the integration layer. Within the integration layer, the technical foundation for the communication of assets is set. To have full visibility, it is necessary to have a change log of condition of the asset and is made available to the information layer. This layer includes IT connected devices as RFID readers and sensors.

The asset layer describes entities from physical as well as digital elements as circuit diagrams. They are passively linked to the integration layer and can be accessed e.g. via QR Codes. The human itself is a part of this layer [13]. The layer architecture requires a standardized communication process and language to enable a plug and play compatibility of products or machines. Solving this issue, the initiative designing RAMI 4.0 also suggest an Industry 4.0 component which serves as an interface between Industry 4.0 communication and the physical asset. This component stores all information of the asset and provides a standardized communication interface. Even passive assets that are not communicating or generating data can be attached to the Industry 4.0 component. [17]

The component consists of one or more (physical or digital) objects and an administration shell. Though each asset requires a shell, multiple assets can be grouped by themes and have a common administrative shell, e.g. various field devices can be grouped in a control device. The shell should contain the virtual representation (digital-twin) and technical functionality. A manifest of the digital twin includes the necessary technical and administrative details to attach the component to the Industry 4.0 environment. The resource manager enables IT services to access data and functions of the administrative hull from outside the objects. The industry 4.0 componentisshown in (Figure 8).

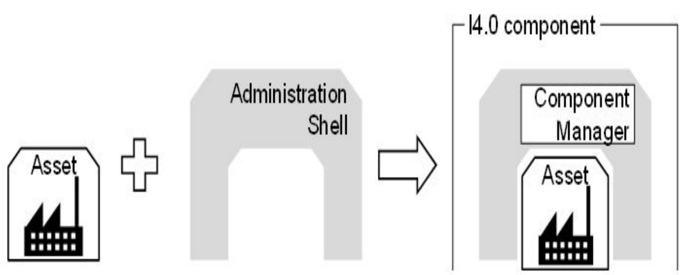

Figure 8: Industry 4.0 Component.

It is due to the usage of this component design, that an Industry 4.0 based communication between objects can be realized in a way that each object can communicate with the other. The vertical integration can be realized because of continuity in component design.

By following the RAMI framework, when applying Industry 4.0 to the manufacturing industry, machines will be able to communicate with each other (Machine-to-Machine, M2M), human machine interaction (HMI) and collaboration will be enhanced, and algorithms can detect malfunctions within production which, in consequence, will reduce downtimes and improve efficiency. The next chapter will investigate the effects of Industry 4.0 when applying it to a manufacturing organization.

Effects of Digitalization on the Manufacturing Industry

This section will outline the implications of the digitalization on the departments of product development, product lifecycle management, logistics as well as marketing and sales.

Product development

Within the 4th industrial revolution the assembly of new products and machines will shift towards customer site. While the product's complexity is shifted from physical to digital, the physical component is to be simplified. This will also transfer a larger part of the value creation to the digital product development. Products will require a communication capability to enable remote software updates as well as a smart component-both will enable new business models. Due to the connectivity, the manufactures responsibility for the products does not end after the products shipping as a cloud based backend might be required [18].

This backend includes the elements illustrated in (Figure 9). Within the backend, APIs (application programming interface) structure how data is exchanged between the database and any software accessing it. The stack includes a database, a server-side framework, a server and an operating system.

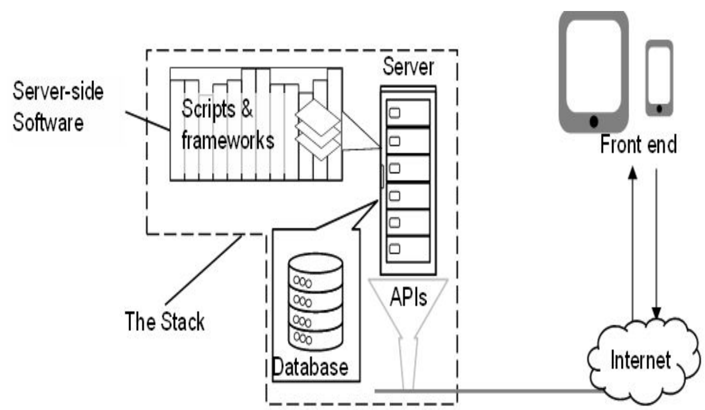

Figure9: Back-End Development & Frameworks in Server-Side Software [19].

Product lifecycle management

Integrated software that combines production development lifecycle with requirements management, simulation, quality management, configuration management as well as collaborative workflow planning and management realizes continuous engineering [9]. This will increase efficiency and speed of product development and hereby reduces cost. Therefore, the manufacturing industry needs to unify their Enterprise Resource Planning (ERP), Product Lifecycle Management (PLM), and Manufacturing Execution Systems (MES) to realize closed loop development [20]. Continuous engineering, digital twin and digital thread are just some of several terms for the creation of an interacting product development based single platform or database. Following the concept of lean, wasted time in product development will be reduced significantly resulting in the change of an information carrier. ERP software suppliers therefore enhance their product portfolio towards a holistic, interconnectable system which realizes the digital thread. The solution for the close looped concept of PTC is illustrated in (Figure 10). The products data can be accessed and utilized in all phases of the products life [21].

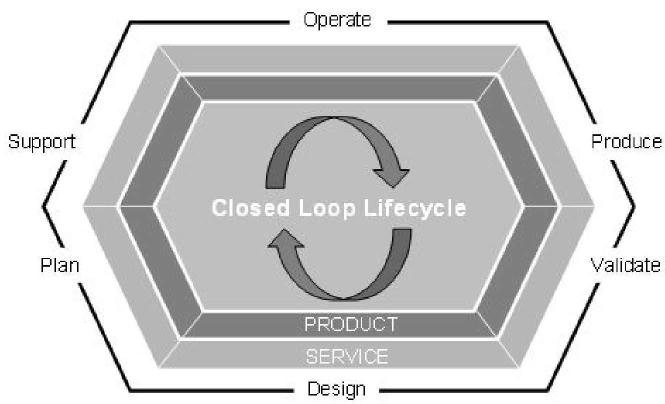

Figure 10: Closed Loop Concept of PTC Creates a Digital Thread.

Logistics

In the logistics sector, advances in manufacturing industry owed to process transparency, is common. RFID and other tracking technologies are long known and are now part of Industry 4.0. In fact, the term "Internet of Things" was formed by the Massachusetts Institute of Technology, Boston U.S., as they were researching RFID in the 1990s. Technologies within logistics like smart boxes, shelves and containers, and autonomous vehicles can also be defined as Cyber physical systems. When logistic data is made available to the IoT platform/environment, automation of processes is necessary as systems complexity, dynamics and individuality is increasing rapidly [14,22].

Marketing

The digitalization enables the shift from selling as a one-time transaction to a maximizing of customer's value over time. By utilizing the data provided by customer's product usage, organizations can measure which features of a product fail or are preferred. Furthermore, analysis of the data will show patterns that enable finer customer segmentation. This paves the way for special after sales packages for the specific segment, increasing sales and customer satisfaction. Focusing the customer's value proposition and correlating their needs to products will make them a part of larger systems. Sales teams will require training to position their offerings in connected systems. Therefore, a partnership with former competitors will be necessary to join products to leading platforms [14].

After Sales

Currently, after sales services are inefficient as technicians often require two trips to the customer. The first trip is required to identify the failure which is repaired on the second. Connected products allow remote, proactive and preventive services. When problems can be identified remotely, the efficiency increases significantly. Product repairs are also done remotely like remote repair of computers. Preventive services can anticipate potential failures and thereby trigger corrective actions by using the data obtained from network connectivity amongst components [14].

To conclude, enabling and rolling out Industry 4.0 approach throughout the company has significant impact on three aspects: Firstly, full and holistic digitalization of a company's operations; secondly, a redesign of the company's products and services are required, and finally, a closer customer interaction is a necessity [23].

Industry 4.0 Readiness in Technical Textiles Industry

This section presents an approach on how to measure or quantify the Industry 4.0 readiness of an organization. The Industry 4.0 readiness framework is based on a study of the IMPULS foundation of the German Engineer Federation (VDMA). The study investigates the progress/readiness in manufacturing and mechanical engineering industry. The survey is structured in six dimensions that are shown in (Figure 11) [24].

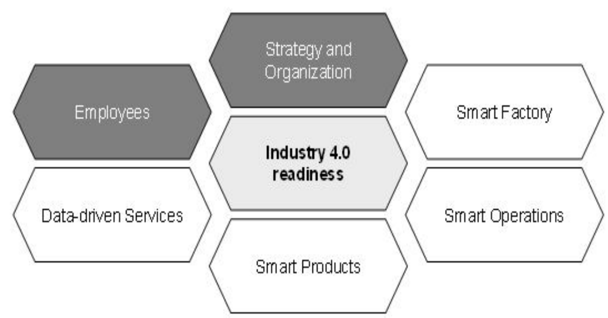

Figure 11: Six Dimensions of Industry 4.0 Readiness.

Deriving from this framework, this paper focuses on the organizational foundations for a successful implementation of Industry 4.0: strategy, organization and employees. These dimensions are not obviously quantifiable and represent the inner readiness for changes to come in the industry. The approach for evaluating the readiness is done as follows.

- The development status of Industry 4.0 implementation needs is investigated. As this status is likely to be non-quantifiable, an alternative approach has to be pursued. Business Models

(BM) are the intermediate elements of strategy and business process. Therefore, the BM can be used to investigate an organization's strategy and workflows. Hence, current business model is to be charted in workshops by using the business model canvas. When reacting to demands and needs of the various stakeholders in Industry 4.0, the BM might require modification.

- Measuring advances in Industry 4.0 strategy implementation requires a metric. This metric or KPI is to be introduced if not yet existent.
- Industry 4.0 will not exclusively affect shop floor and manufacturing, but also sales, services, IT and other parts of the organization. So, the respective department should invest into digitalization. A comparison of financial effort of the departments in Industry 4.0 is the foundation for further recommendations.
- Besides the financial intentions, the anchoring of the organization's innovation management is to be analysed. New technologies need to be acquired and implemented in the organization. Successfully implementing new ICT technology in product and manufacturing environment requires sectorial competencies to be streamlined and developing a cross sectorial technology and innovation management.
- Employees are the key driver for Industry 4.0 and their associated transformation. Their competencies are what make them fulfil their prescribed task. Competencies are the combination of skills, knowledge and attitude. To assess the organizations employees' readiness for Industry 4.0, their skills in relevant technologies are measured.

The outcomes of five proposed areas regarding organizations Industry 4.0 readiness are used as starting points for setting priorities in competency development. The next section describes an approach how to include the demands and needs from external, market and customer driven perspective.

Market Pull

The ideation phase in an organization's innovation process can be started from two sides: market needs (pull) and technology advances (push). The coupling model of Rothwell (Figure 12) combines both perspectives forming the 3rd generation of innovation models [25]. Within this model, marketing and R&D are tied closer together, compared to prior generations. The organizations moved away from individual R&D projects to consolidated product portfolios. The later generations parallelize the innovation process to reduce time-to-market and enhance communication between the departments. Even though, this is not the latest generation of innovation models, it emphasizes the necessity to utilize both major ideation sources in the front end. An approach on how to identify needs of customer and market side is discussed in this section.

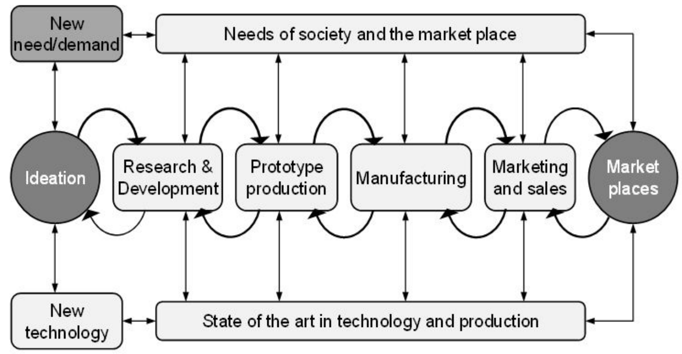

Figure 12: Coupling Model of Innovation Uses Both Technology Push and Market Pull for The Fuzzy Front End of The Innovation Process.

An ideation process driven by customer needs involves low risk and mostly generates short term problem solutions. Even though, those incremental innovations are crucial to the organizations success and customer's satisfaction. Customer involvement is recommended and comparably easy as the customer is also the problem owner. The innovation process is conducted via a stage-gate process. When customers provide a detailed list of demands and problems to solve, the following is compulsory. Identifying stakeholder groups is the first step. These groups can include financial investors, funders and especially customers. Next, the influential factors for the respective groups are investigated. These include mega trends of futurologists, industry trends as well as organizations specific problems. The recommendedprocessisillustrated in (Figure 13).

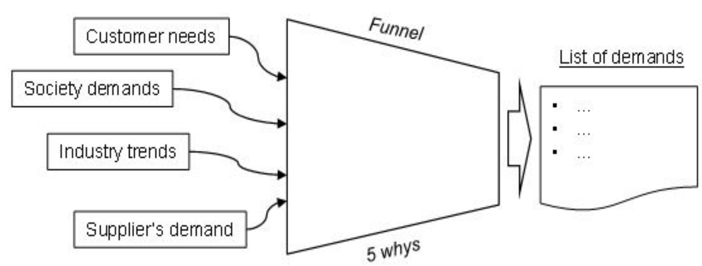

Figure13: Front End of the Innovation Funnel Evaluating Customer and Market Demands.

Technology Push

In the beginning of the last century, product innovation was primary driven by advances in research and development departments that were marketed. This is referred to as technology push. Products are positioned on the market without having insight on customer demands or need for respective technology. The innovation process for technologies is divided into three steps and originates from internal or external sources. The organizations activities in research and development lead to a growing internal technology basis. Company external technologies are accumulated by monitoring technology scouting initiatives as Gartner's Hype cycle. Further incubators for external technology are amongst other papers issued by industry associations, consulting firms or university research. The sources, as well as the front innovation process, are illustrated in (Figure 14).

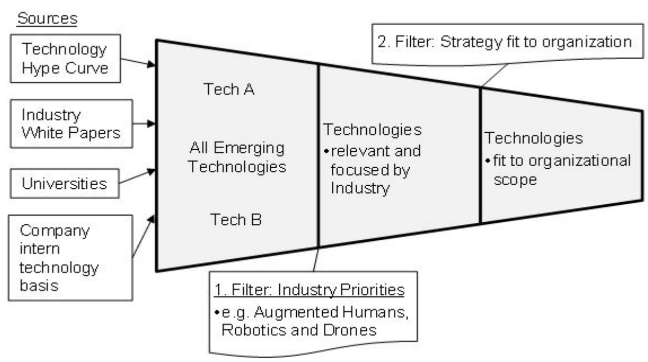

Figure14: Front End of Innovation Process from Technology Perspective.

As the second step based on these external sources illustrated above, a list of emerging technologies is created. To reduce the amount of technologies, the list is filtered by matching the technologies with industry priorities. The advances of the assigned technologies are to be observed. Competitors of a similar industry might focus those as well. In a third step, the technologies should be filtered by their fit to the organizations scope or priorities. Based on this prognosis, organizations can develop and implement professional development for employees before the technology reaches mass market adoption. Combining the Gartner's hype cycle with the curve of technology diffusion, (Figure 15) illustrates the interrelation of technology scouting and skill development.

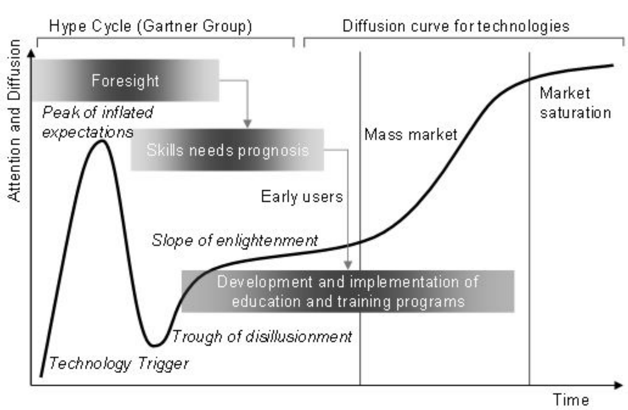

Figure 15: Development Phases of Emergent Technologies Including Recommendations When and How to Derive Skills cf. [26].

Deriving a Competency Strategy

The purpose of this section is to enable the derivation of a competency gap that results on the overlap of the organizations capabilities and the expectations from technology and market site. Therefore, a four-step methodology is presented.

First, the organizations customer's problems as well as societal trends need to be evaluated. Ideally new technologies in the focus of the organization assigned to solve some of the demands. By doing so, it is made sure that the technology capabilities developed are needed to fulfil customer needs.

Within the next step, the technologies that could provide value when addressing customer demands are clustered. Depending on the technology area to consider, the cluster criteria are to be derived. Within these clusters considering emerging technologies, job requirements are to be derived to capabilities (Figure 16).

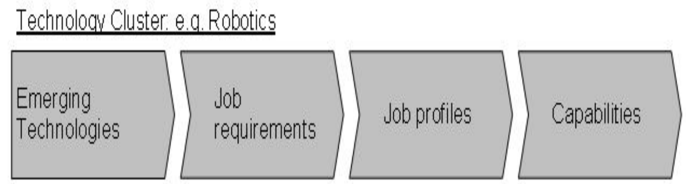

Figure 16: Way forward when Deriving Technology Clusters to Capabilities.

Using these capabilities required providing value to customers with the technologies assigned to the respective cluster and considering the priorities of the organization, a gap of competencies in the organization is derived. Therefore, the capabilities derived in the initial survey on the status quo of the capabilities are required with the desired capabilities. Within this, the manpower and the skill level required are defined.

Finally, considering relevance and size of the gap of capabilities, for each technology cluster sourcing strategies for competencies are discussed. The four options in sourcing are illustrated in (Figure 17).

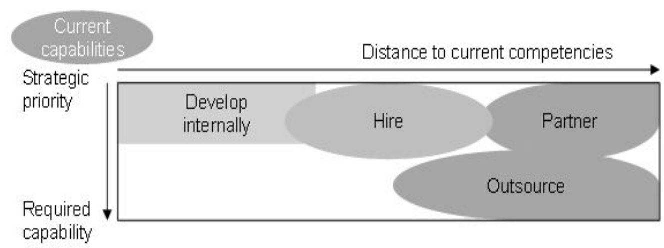

Figure17: Traditional Options for Sourcing of Competencies.

Evaluating Emerging Technologies

Organizations need to monitor technological innovations to maintain their market position. When analysing emerging technologies, there are various sources to evaluate. The information sources can be formal, e.g. statistics, market reports, data bases, external commissioned study, and informal e.g. conferences, interviews, expert talks, R&D cooperation. (Table 1) presents the technological priorities of the technical textile industry.

The technology priority groups in the Technical Textile Industry for ICT technologies	
• Augmented Humans, Robotics and Drones • Advanced Analytics and Big Data • Augmented and Virtual Reality • Cloud Services	• Additive Layer Manufacturing • Internet of Things • Collaboration • Mobility • Artificial intelligence

Table 1: Technology Priorities of the Technical Textile Industry.

The filter criterion is whether or not the item of the list can be aligned to the industrial priorities. So, some technologies are screened out the organization's scope in technology monitoring. The list showing the industry focused technologies using the initial sources mentioned above after applying the first filter is illustrated in (Table 2) whereas (Table 3) lists the initial technology priorities of the technical textiles industry.

Watch List of New Emerging ICT Related Technologies in Industry Focus	
• Advanced Machine Learning and Artificial Intelligence • Big data analytics and advanced algorithms • Brain computer interface • Cloud computing • Swarm Systems • Conversational user interface • Digital twins • General purpose machine • Gesture control device	• Human machine interface • Intelligent apps • Intelligent things • IoT edge architecture • IoT integration • IoT platform • Natural extension of human abilities • Smart Robots • Smart Sensors • Virtual & augmented reality • Virtual personal assistants

Table 2: List after Applying Industry Focus and Clearing Data.

Important Technology Cluster of Industry 4.0	Technical Textile Industry's Focus
• Robotics	• Priority and initial experience
• Tools for data analytics	• Only collecting data is not enough, value lays in the analytics
• Mobile devices	• Relevant for application
• Cloud platform	• Know-how on utilizing cloud solutions
• Real time decision support	• Highly relevant in quality driven technical textiles industry but postponed
• Connectivity technology	• Requirements definition for selection of connectivity technologies for smart weaving and knitting machines
• Sensors	• Requirements definition for selection of connectivity technologies for fabric and yarn production

Table 3: Initial Technology Priorities of the Technical Textiles Industry.

Technologies related to robotics are prioritized in line with Industry 4.0 efforts. Though, to provide insight to others on designing smart factory, know-how of technologies related to connectivity technologies, sensors and mobile devices is required. Cloud platforms are needed to store and manage data generated in the factory; therefore, application know-how in this technology is required as well. Preparing predictive decision support systems is currently out of focus as other technology competencies. As this cluster requires knowhow in the other technology clusters, the focus might change after progress in efforts in Industry 4.0.

The Shortlist of Emerging Technologies in Focus Consists of

- Smart Robotics, Natural extension of human capabilities
- Intelligent things, smart sensors
- Big data analytics and advanced algorithms

Evaluating Expectations and Current Capabilities

Where technology push and market pull overlaps, the window of opportunity opens for innovations. Therefore, the insights on market demand and development of emerging technologies are merged with the industry's specific status quo analysis. Based on the current capabilities, the strategic priorities and the technologies and demands of the prior chapters, technological priorities are derived. Based on the capabilities, recommendations are given on how to source the gap of competencies in the focused technology clusters.

Possible Technologies to Meet Market Demand

In mind of the skilled aging workforce in the textiles industry, employees might require assistance on physical level when continuing working on not ergonomically designed assembly lines. Therefore, introducing new technologies to the manufacturing environment might be required. For example, powered exoskeletons might help ensuring physical challenges of the workforce. Also, highly adaptive robots working shoulder by shoulder (cobots) with employees might provide value. By shifting operational expenses (wages of employees) to Capital Expenditures (CAPEX), cost reduction requirements in textile manufacturing can be met.

Besides the cost saving, the process visibility on the shop floor can be enhanced via utilizing quality control right at the workstation of the robot. For this, the right sensor technology needs to be applied measuring the quality of the parts manufactured in real time. Also, the generated sensor data might be used to identify at which exact position on a manufactured part has quality issues.

Meeting the market demand of knowhow in implementation of industry 4.0 initiatives, knowhow should not be exclusively developed on physical shop floors but also in the handling of the generated data of the smart factory. This is the basis for real time decision support systems and dashboards visualizing the current status on the shop floor. Hence, problems might be identified immediately and mitigation measures can be launched.

Derivation of Technologies to Competencies

Following the organizations scope in Industry 4.0, for each technology cluster the emerging technologies are listed, requirements for employees are derived, possible job titles are presented and most importantly, the capabilities required to fulfil this task are outlined. In (Table 4), the prioritized technology clusters are discussed.

Cluster	Cloud Computing	Real Time Decision Support	Mobile Devices
Job Requirements	• Host and provide backbone to shop floor sensors and devices • Store and process data demanded by data analytics team	• Similar to MES software • Currently out of companies focus	• Provide shop floor workers with the right information at the right time. • App development for company specific focus • Visualization of progress, next job etc. • Foster communication with production planning and engineering
Possible Job Titles	• Cloud Architect • Cloud Specialist		
Capabilities Required	• Data integration and analysis skills • Mobile app development (front-end for cloud application) • Experience in cloud technology and architecture		• Required to connect blue collar workers to the manufacturing IT (mobile ERP access) • In deep understanding on ergonomics and usability

Table 5: Derivation of other Technology Clusters to Necessary Capabilities.

If the three clusters draw more attention in the future, cloud technologies might be in the responsibilities of the software engineer as well as the real-time decision support system. The utilization of mobile devices on the shop floor require knowledge on the working environment on the shop floor but also the connectivity to the servers and are therefore a shared responsibility of the two job profiles. The separation of technology cluster is summarized in (Figure 18).

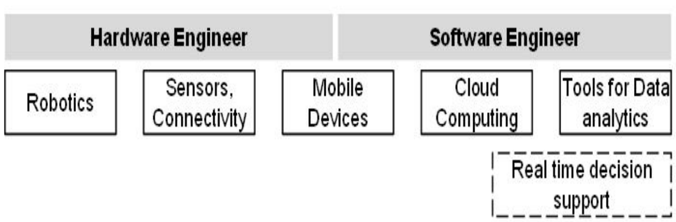

Figure 18: Understanding Competence Distribution between New Job Positions Due to Industry 4.0.

Defining A Strategy on How to Close the Gap of Competencies

As illustrated above, there is a gap of competencies in Industry 4.0 related ICT skills. New employees or trainees have to be assigned to the workforce in order to close the technology implementation gap. Depending on the delta of desired to existing competencies, four options can be derived. Depending on the circumstances, the capabilities are developed internally, employees with the skillset are hired, a strategic alliance is initiated or the capability is outsourced (bought in as a subscription model or via subcontracting). The criteria for each option in sourcing capabilities are outlined in (Table 6).

Option in Sourcing Capabilities	Assessment of Each Option Regarding Requirements, Pros and Cons
Develop (internal)	A basic understanding of technology exists in-house. The skillset is ideally not spread out over all employees but focused on small group of potentials / talents. There are capacities of employee for professional development. + Involves less risk and costs compared to hiring + Increase in employees' motivation levels - Development can take longer - Promoting employees to the wrong job will lead to increased attrition rates
Acquire (Hire employee) (internal)	There is currently little or no understanding or capability in-house. The required competencies are essential to value proposition. + Likely to increase the team's skillset + Bring new ideas to the organization - Higher recruitment costs - Adapting to the organizations culture / working environment

Build strategic alliance (external)	Strategic alliances do not necessarily involve monetary payment or a binding contract. Business entities collaborate to mutually benefit from it. The objective is to acquire skills and capabilities that would be too costly to incubate in-house. + Remain in control of assets + Risk reduction, expansion of business model + Increased opportunities - Finding suitable partner for strategic alliance
Outsourcing (external)	Outsourcing involves the contracting of services in exchange for payment to minimize or limit resources that would be required when performing a function internally. There is no access or ownership towards the capabilities and skills. + Risk reduction + Expansion of business model, Increased opportunities - Financial contracting - No access to competence, dependence on external party

Table 6: Assessment of Criteria Pertaining to Capability Requirements.

Since know-how neither in data analytics, cloud computing or mobile devices applications is part of the core business of the organization but strategically important to the success of Industry 4.0 projects, hiring an employee with the required know-how is recommended.

Recommendations and Risk Evaluation

Originating from prior analysis of the status quo, customer demands as well as technology advances and assessment of capability gaps, recommendations for actions are outlined in this section. These are structured in three stages:

- Competency development within the organization by professional training to prepare individuals and the entire workforce.
- Increase in technical and managerial competency through experienced new hires from outside the organization/industry.
- Infrastructure and organization orientated recommendations

The set of recommendations should be seen as strategic guide rails to transform the organization and the organization's employee mind-set. This can only be achieved in a dual approach creating a need for change from top-down as well as the willingness of the employees in extending their knowledge base towards versatility (bottom-up).

On order to further develop the competitive service offerings for Industry 4.0 related services, a typical project cluster consists of three individuals: a software engineer, a hardware engineer and a team lead.

Competencies : Professional Development and Training

Professional development of employees either internally or externally is used tool to build competencies for Industry 4.0. Industry 4.0 will affect the entire workforce, so various options are presented to prepare the individuals.

No competency building or changes can occur, if the workforce is not willing to learn and adapt new things. An inner motivation or readiness of the employee in building and changing workflows and processes of the daily routine is required. Due to the increased complexity in the manufacturing environment as ICT solutions are moving on the shop floor, there is an increased demand for interdisciplinary thinking and action to provide best value to the organization. Know-how on various technologies is required, demanding a willingness of lifelong learning of the employees.

Design thinking will provide employees to better identify customer's needs. When asking the right questions to the right stakeholder, generates ideas thereby providing concepts for prototyping and utilizing feedback to iterate several options in short time duration. Such an approach is likely to increase speed of innovation as well as success rate.

System thinking will help identify and understand dependencies of the problems and solutions "ecosystem" which supports the alignment of the various stakeholders in the connected enterprise. The objective is to increase speed of innovation and development by having the right point of view in terms of scale and scope of innovations.

After completing design thinking workshops, an introduction course to agile project management is recommended. Within this framework, a basic understanding will help decide when to apply agile methods and when to follow traditional project management techniques.

These workshops can be conducted by a select group of employees that gain knowledge and thereafter disseminate the lessons learnt to the rest of the team. The overall objective should be to foster creative out-of-the-box thinking, increase the innovation attitude and enhance critical thinking, which is required to meet the changes in soft skill demand.

Further, in addition to general training offering, the hardware engineer should conduct additional trainings. Besides, workshops offered on entry level in innovation competency building, the employee retrained as a hardware engineer should be a thought leader in the use of new ICT/robotic technologies on the shop floor. This will require building demonstrable case studies for new technologies to gain practical experience and knowledge. Failures resulting from experiments of new technologies or ideas must be accepted, and learnt from, by the organization's leadership as this will provide the path for future developments.

Specifically, the hardware engineer should build a database for sensor and connectivity in which an evaluation for the application is given. So, the retrained engineer is to be able to decide which technologies to use when customizing manufacturing machines to enable vertical integration of the factory. In robotics, knowledge is recommended to be built during concrete projects via professional development for the concrete use case.

In the best case, these exercises lead to quick wins thus resulting in higher Return on Investment (ROI). Building competencies in agile development is crucial for the success, as technologies emerge quickly and environmental changes in the shop floor environment are expected to occur more often. Quick wins are important for the acceptance of the workforce in the organization's strategy shift. They are also necessary to show the leadership that the investments in retraining will pay off as new projects can be acquired based on the competency built.

In the long run, an understanding on the case studies for automation and robotics needs to be built. Knowhow on sensors and connectivity technologies can be accumulated by building solutions for the organizations shop floor activities. A thorough understanding can be built by using technologies and sensors for robotic applications and trying the right applications.

Competencies: Hiring of New Employees

When competencies are required for the organization and seen as a strategic competency, skills should be developed in house. When the gap of skills of the current employees to the current tasks is too large, new employees should be hired. Though, the costs and time for hiring are high, the developed competency is in-house and easily accessible. Though, when building new competencies in an organization, hiring new employees is the third most popular choice of organizations (44.1 %) surveyed in an Acatech survey [27].

In case of the Textile Industry, cross-collaboration with other group along with hiring is recommended to close the gap of competencies in data analytics. For the job of the software engineer, a strong emphasis on statistical and analytic skills in the educational background is recommended. As an initial ideation list (Table 7) for a job advertisement for this future employee, the job profile of a data analyst is illustrated.

Data Analyst Skill Requirement List
1)Technical skills:
• Statistical methods and packages (e.g. SPSS)
• R and/or SAS languages
• SQL databases and database querying languages
• Programming (e.g. XML, JavaScript or ETL frameworks)
• Database design
• Data mining, Data cleaning and managing (simple and intuitive way of data preparation with a graphic tool)
• Data visualization and reporting techniques
• Machine learning techniques (e.g. with Python)
2)Business / soft skills:
• Analytic problem solving
• Effective communication
• Creative thinking
• Industry knowledge

Table 7: Data Analyst Technical Job Profile.

Though some of these skills are specific, mainly the mindset on data orientation as well as the willingness and motivation to learn how to provide value from data is what is being sought by organizations. Ideally, a new employee would bring in digitalization competencies e.g. business model thinking. The new hire should contribute to the Industry 4.0 team's capabilities that are listed below:

- Data handling
- Digitalization competencies (e.g. business model thinking)
- Personal skills as self-organization, project management and creativity
- Knowhow on manufacturing processes and service management
- Technology related competencies in robotics, sensors, and shop floor related hard and software (bridge to MES)
- Lastly, social competencies to convince others of the need and urge of the new core competencies within the organization and to acquire projects in this field

Recommended Adjustments on Organizational Level

Besides the recommendations on building capabilities of individuals the organization needs to provide the setting for the team to work successfully. Therefore, recommendations on organizational level are given in this section.

Leadership

The organization's leadership should drive and lead initiatives of Industry 4.0. Building a new team inside the organization requires financial and strategic commitment as well as development and leadership support. By committing to such a cause, the leadership encourages the momentum of the transformation throughout the organization. Therefore, the leadership should create awareness for the need to pursue these initiatives by showcasing the impact on the entire textile manufacturing industry as well as the impact on profitability and improved efficiency of SMEs.

Systematic Review of Industry 4.0 Implementation

A review of the status of implementation is recommended to ensure that enough projects in Industry 4.0 are acquired to fund the initial investments and hire. If the advances of the projects related to Industry 4.0 are not tracked, the new team loses priority and momentum.

Therefore, a key performance indicator is to be introduced that balances efforts of tracking and value in information. It has been shown, that proportional to the size of the organization, the likelihood of using KPI to measure advances in Industry 4.0 increases. The table below outlines possible candidates that meet the prior mentioned demands (Table 8).

Scope of KPI	Explanation	Focused KPIs
Input KPI	Measure assets and resources invested in or used to generate business result Ratio of projects allocated to Industry 4.0 and all projects.	• Time of employee spend on Industry 4.0 projects compared to man-year • Ratio of projects allocated to Industry 4.0 and all projects
Output KPI	Measure the financial and non-financial results of business activities.	• Industry 4.0 revenue by department • Rate of innovation: builds the ration of revenue generated of new products and services and total revenue
Process KPI	Measure the efficiency or productivity of a business process.	• Project lead time reduction due to e.g. digitalization of workflows • Costs reduced due to digitalization projects on shop-floor or office floor

Table 8: List of Possible Kpis to Measure effort or Success in Digital Transformation.

Partnering

The organization should consider partnering to gain expertise in relevant technologies related to Industry 4.0. As prior states, to gain competencies in cyber security, it is recommended to train a focal point within the organization for cyber security. When implementing smart factory solutions, this knowledge on security will support the offering of a holistic solution to customers and reduce concerns regarding ICT technologies on the shop floor.

Further, a supplier of data storage management needs to be selected. As prior discussed, cloud computing providers offer scalable solutions, to store and manage the growing amount of production data. The organization does not need to invest into physical hardware before starting smart factory projects. Pay-per-use or subscription models are cost models of the providers which ensure high visibility and flexibility in cost structure. Cloud providers also offer tools and platforms to connect IoT devices to the cloud, store the relevant data and process the data to provide value.

Risk Mitigation

This section will discuss risk identification and mitigation strategies for the recommendations given in the prior chapters. Cyber security is the biggest challenge for manufacturers using Industry 4.0 as stated in (Figure 19), as new, formerly unknown cyber risks are introduced to the organization. In the traditional IT, the manipulation of smart tools or the hacking of robots and cobots has not been a concern. For IP sensitive research areas and products, this is a major risk due to the regulative, safety and security driven nature. More connectivity in the factory will increase the threat of cyber-attacks.

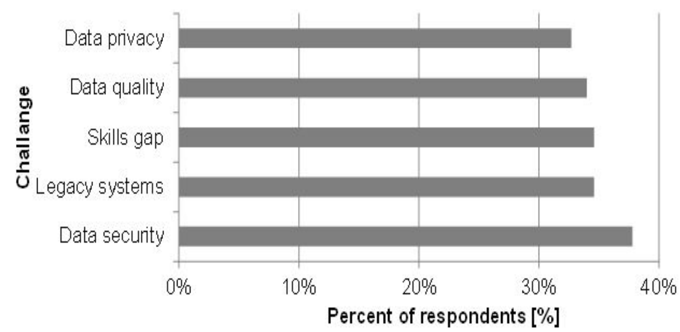

Figure 19: Top Challenges for Manufacturers in Smart Manufacturing.

In terms of cyber security knowledge, inadequate information is readily available currently within the organisation. Therefore, it is recommended to build capabilities by learning about security practices by applying them in the planning phase of new Industry 4.0 projects. Further, a focal point on data and cyber security is to be built within the organization that will increase awareness among all employees and provide further training and security consideration to Industry 4.0 projects.

Change management

Employees are the centre of all activities in change management. Organizational structures and processes can only change when employees are capable and willing to adapt change and go along with it. Reasons of human sceptics or slowdown in following the recommendation made are likely to be due to missing capability in learning on new technologies or e.g. fear for substitution of blue or white-collar workers, fear of steep learning curve, etc.

When intensifying efforts in the use of digital technology for the textile manufacturing, four groups within the workforce are likely to appear with a typical distribution as illustrated in (Figure 20). To succeed, especially opponents need to be engaged in the transition process while reducing the perception of personal risk for the employees.

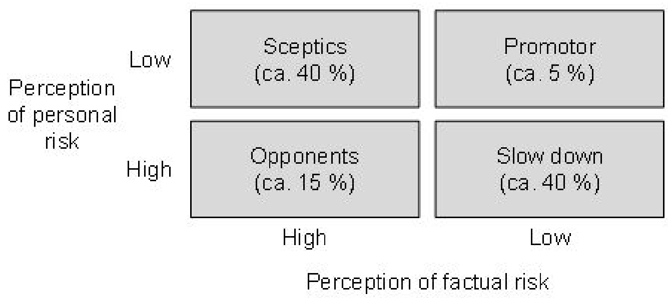

Figure 20: Attitude towards Change.

The risk mitigation strategy in change management is to be done in four phases: information, motivation, participation and professional development. The employees need to be informed on the relevance of the changes for the organization and the individuals. It further is to be explained, how the team of Industry 4.0 employees will work in the future and the transition process to this needs to be communicated. Employees need to be motivated to be engaged with the use of new technologies or working methods. Therefore, an inner willingness is to be created. The benefits of building new capabilities as an organization itself and individuals themselves are to be shown when participating in such transformational activities. The organization is likely to be prepared for future customer demands. Lastly, as prior recommended, professional development in the fields of Industrial ICT technology is to be offered.

Summary and Outlook

Textile based solutions are now being applied to several industries like aerospace, automotive, sports, medicine, etc. To meet low cost product requirements, OEMs need to foster productivity while maintaining quality standards. With the upcoming fourth industrial revolution, new possibilities in improving operations appear that are able to cut cost per aircraft by reducing time-to-market, forecast accuracy and reduction of machine down time among others. As an example, these potentials add up to potential cost reduction of 3.7% p.a. in aerospace Industry. Before starting Industry 4.0 initiatives, organizations need to set up a strategy.

To achieve the strategies objectives, organizations are required to build capabilities in digital technologies to realize the economic potentials behind Industry 4.0. Therefore, this paper provides a methodological approach to determine an organization way forward in building digital competencies to benefit from the value creation potential of Industry 4.0. The foundation of the methodology is the assessment of the Industry 4.0 readiness of the industry which was examined as the status quo. This involved the analysis of the typical business models currently used and existing measurable knowledge in I4.0 technologies. For Industry 4.0 related projects it is recommended to build a new team within the organization.

The new team is proposed to consist of a team lead and the aforementioned software and hardware engineers. As some capabilities in hardware applications of I4.0 already exist in the organizations, an internal employee ought to receive professional development empowering and fostering capabilities in robotics, sensors and connectivity. Partnering and building capabilities in Cyber Security is necessary to provide safety by design solutions to customers and to mitigate risks that increase within smart factories.

As a next step, the methodology developed could be extended by providing and promoting specific training catalogues for all employees to further increase and build a digital mind-set among the workforce and to build digital capabilities. In line with this, generic training should be considered as well as small prototyping ideas to develop an understanding of the technological possibilities. Apart from this the new acquired capabilities could be used and investigate the potential new business models for the organization by using digital technology.

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