IMPLEMENTING INDUSTRIE 4.0 STRATEGIES: BEYOND TECHNICAL INNOVATIONS

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Abstract
Industrie 4.0 as a concept is becoming increasingly popular in German speaking academic literature, German industrial organizations as well as in German Government. This article provides an overview of what Industrie 4.0 is and suggests a simple framework to look at and analyze its economic implications at the firm's level. While many activities are under way to deal with and solve open technical issues, comparably little focus seems to be given to installing Industrie 4.0 supported processes at the shop floor and ensuring that employees have necessary qualifications to be able to successfully operate the new systems. Finally, strategic implications of the so-called 4th industrial revolution are elaborated on. The article closes with remarks on future research opportunities.

Keywords: Industrie 4.0, internet of things, innovation, processes, qualification

JEL Classification: M10, O3, L2

Introduction

Industrie 4.0 has been launched in 2011 by the German Government as one of several high-tech initiatives to secure the competitive advantage of Germany as a manufacturing and knowledge based economy. During the Hannover industry fair in 2011 the initiative was introduced to the public (Kagermann et al. 2011). Claiming for nothing less than the 4th industrial revolution, the initiative quickly picked up pace. In April 2013 first recommendations how to implement Industrie 4.0 were published by the Communication Promoters Group of the Industry-Science Research Alliance (Kagermann et al. 2013). Since then, a national research platform called \`Plattform Industrie 4.0´ has been launched by the German ministry for economic affairs and energy and the German ministry of education and research, and the associations BITKOM, VDMA and ZVEI. The platform provides a forum to join efforts to develop Industrie 4.0 solutions for the German economy. Working groups dealing with issues like standards and norms, research and innovation, IT security, legal framework, and education and training systematically drive the initiative forward. Overarching goal of the initiative is to help Germany to position itself as a major player in the digital industry to come, both globally as well as nationally.

Initiatives similar to Industrie 4.0 have been launched in other countries like Japan (Industrial Value Chain Initiative IVI and IoT Acceleration Consortium IOTAC), the US (Industrial Internet Consortium, IIC), UK (High Value Manufacturing), and China (Smart Factory 1.0 and Internet Plus both embedded in the overarching Made in China 2025 strategy) (Kagermann et al. 2016). However, most of these, including Industrie 4.0, focus on technical aspects. So far, relatively little research has been conducted regarding the impact of Industrie 4.0 on organizational implications and competitive strategies. This article provides thoughts and recommendations in these directions.

Industrie 4.0 – what is it?

For this paper we adopt the definition of Sucky et al. (Sucky et al. 2016): "Industrie 4.0 is the equivalent of the 4th industrial revolution, the next level of organizing and controlling the entire value network beyond the lifecycle of products. This is enabled by connecting Cyber Physical Systems (CPS) in Production and Logistics with the Internet of Things to a supporting infrastructure. This way all involved instances of the value chain are connected to each other, information can be provided in real-time and it is ensured that by autonomous interaction and self-regulation of all instances of the system the value adding process runs better. All these are prerequisites to enable individualized products in highly flexible (mass) production setups." (original quote translated by authors). Cyber Physical Systems are "physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core."(Rajkumar et al. 2010). Generically spoken, the Internet of Things (IoT) "refers to a global, distributed network (or networks) of physical objects that are capable of sensing or acting on their environment, and able to communicate with each other, other machines or computers" (Davies 2015). IoT together with other concepts of Digitalization will not only impact the way products are being developed and produced but also how services will be rendered in the future. Smart services will provide value to customers which, with today's infrastructure, cannot be offered (Marquardt 2017) while knowledge intensive business services will expand into new industries, e.g. energy network consulting and management (Weber et al. 2016).

Stakeholders, business alliances as well as research and standardization bodies push the concept of IoT further, either approaching it from the 'internet' or from the 'things' perspective (Atzori et al. 2010). However, numerous technical, standardization, information security and privacy protection issues need to be resolved to allow for widespread use of IoT in an industrial context (Xu et al. 2014).

In our paper we focus on aspects beyond technical innovations. Therefore, we assume that all technical challenges have been met and that digital entities and physical devices with embedded identification, sensing and/or actuation capabilities can be linked and communicate with each other (Miorandi et al. 2012). Early real-world and test applications demonstrate that smart factories are already possible with today's technology (Wang et al. 2016).

For our analysis, we use the framework shown in Figure 1. According to this framework, Industrie 4.0 can be described by a technical dimension (largely identical with IoT in an industrial context as discussed above), a process dimension and a human resource dimension. We will discuss the latter ones in more detail in the next two sections of the paper. Finally, we will have a look at strategic implications of Industrie 4.0.

The Process Dimension of Industrie 4.0

With Industrie 4.0, automation will become possible for increasingly smaller batches of production (Spath et al. 2013). Vertical integration within value chains as well as horizontal integration across industries can be expected to significantly impact and drive domestic and global competition (Kagermann et al. 2016). While from a technology perspective it is important to understand and have appropriate tools to assess the readiness to implement Industrie 4.0 solutions, especially for small and medium enterprises (SMEs) (Leyh et al. 2016) too much of a concentration on the technical implementation carries the risk of missing the vision of Industrie 4.0 and hence the benefits that come with it. Industrie 4.0 is nothing less than a shift in paradigms how to set up and run not only manufacturing systems but complete value chains (Selim & Schumacher 2016).

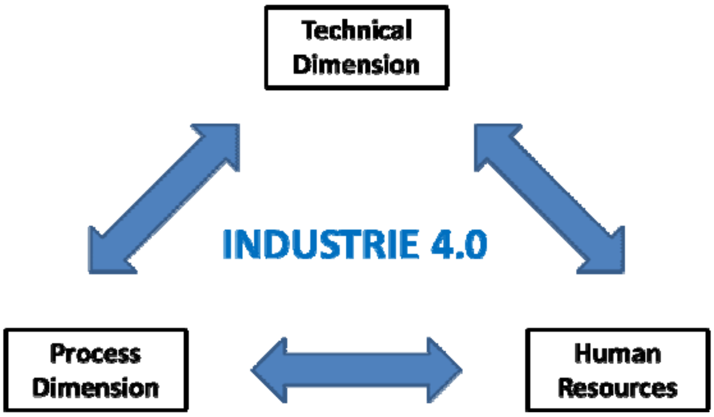

Figure no. 1: Industrie 4.0 Framework

Source: authors' contribution

It is widely accepted that Lean Manufacturing is one key element of Industrie 4.0 (Spath et al. 2013; Frank 2014). In fact, much of what Industrie 4.0 stands for can be viewed as implementing Lean Management principles (Womack & Jones 2003) using new technologies. While the Toyota Management System, which served as the blueprint for the Lean Management approach, already considered Product Development as one of the seven key functional areas to be coordinated (Monden & Talbot 2004), Industrie 4.0 has the potential to take things yet one level further by fully integrating all Engineering activities into the value chain (Kagermann et al. 2013).

Since both Industrie 4.0 as well as Lean Manufacturing aim for continuous flow and one-piece-production it is the opinion of the authors that designing plant layouts, processes, workflows, and supporting activities can principally follow the same logic as in a "low-tech" Lean Transformation scenario (Bicheno & Holweg 2009). However, given the advanced technology required to implement Industrie 4.0 and that many projects will take place in a brown-field environment (i.e. within existing production facilities) it may be useful to follow a three step approach by: firstly developing a common understanding of what Industrie 4.0 stands for in a particular business unit, secondly identifying internal and external pre-requisites to successfully implement Industrie 4.0 and pulling together a road map, and lastly setting up and executing specific sub-projects (Selim & Schumacher 2016).

Under Industrie 4.0, raw materials, components and finished products become "intelligent" insofar that, enabled by sensors and actuators, they can send and receive information regarding their history as well as their requirements towards future production steps. Within adequately designed manufacturing layouts this allows for individual and ad-hoc, self-optimized material and production flows. Predictive maintenance supports low levels of machine downtimes, helping to stabilize manufacturing processes (Wegener et al. 2016). Based on experiences from Lean Manufacturing significant improvements in quality, delivery time and working capital can be expected (Womack & Jones 2003).

Industrie 4.0 processes will allow new business models currently not thought of. Personalized products and services at costs close to mass-production will allow new, flexible offers to commercial (B2B) and private customers (B2C) (Spath et al. 2013). Further, supported by full integration of the value chain, information flow from customers to businesses (C2B) will allow manufacturers to tailor their offers much more precisely, even those not personalized (Hüther 2016). Mass data analytics (Big Data) provides tools to extract valuable information from cloud storages to configure product offers which were not available before. Estimates quote improvement potentials to the operating margin for companies fully making use of Big Date analytics of up to 60% (Kambatla et al. 2014).

Broad-scale implementation of Industrie 4.0 technology and processes requires significant investments into infrastructure, both financially as well as in terms of required manpower. Therefore, it is highly likely that the 4th industrial revolution will be executed evolutionary (Spath et al. 2013). This causes problems particularly for small and medium-sized enterprises (SMEs) which are the backbone of Germany's industrial sector. Getting this group integrated into global value networks requires the design and implementation of comprehensive knowledge and technology transfer and best practice sharing (Kagermann et al. 2013). For Germany, the internet platform Industrie 4.0 (www.plattform-i40.de) has been launched by the German ministry for economic affairs and energy and the German ministry of education and research to support such sharing of knowledge.

The Human Resource Dimension of Industrie 4.0

Smart factories will still need humans to run them (Hirsch-Kreinsen 2013). Direct and indirect production tasks as well as planning and execution will diffuse with Industrie 4.0 technologies and processes being implemented (Spath et al. 2013). Traditional automated manufacturing systems with clear distinction between humans and machines and centralized controls will be replaced by cooperative work-systems consisting of people, machines, robots, and IT-systems. One key aspect in such systems is to develop and provide new approaches for learning to enable required process innovations (Welter et al. 2016). Approaches to structure learning content according to the degree of formalization, specialization and job complexity of specific workplaces have worked well in relatively stable production environments, where main focus was to train people for a particular job on the line. For Industrie 4.0 set-ups, structured and unstructured learning-by-doing or learning-by-observing will have to complemented by IT supported learning tools (like head mounted displays) who provide on-site, context-sensitive information and allow the user to simulate consequences of possible action alternatives without having to go through a physical and potentially costly trial-and-error process (Mühlbradt 2015).

However, in order to educate or train their staffs for Industrie 4.0, management first has to understand what qualifications are required for employees to fulfill their current and future jobs. Generally speaking, qualification can be viewed as acquiring competences in the four areas (Hecklau et al. 2016): 1) technical competencies (job-related knowledge and skills), 2) methodological competences (skills and abilities for general problem solving and decision making), 3) social competencies (skills, abilities and attitude to cooperate and communicate with others), and 4) personal competencies (an individual' personal values, beliefs, and motivations).

There is general agreement in the literature that qualification requirements in Industrie 4.0 production systems are highly context specific. However, driven by the high level of automation and the interaction between humans and machines to run complex, IT-controlled production processes, following job elements and corresponding competencies will become more important in Industrie 4.0 scenarios (Ahrens & Spöttl 2015): 1) interaction and collaboration of shop-floor employees with engineers and other experts to design Industrie 4.0 products and supporting software, 2) analysis of work-processes, 3) adaption of pre-configured software to company-specific requirements, 4) communication into other areas of the organization, e.g. logistics and accounting, 5) software installation and integration into existing networks, 6) physical implementation of Industrie 4.0 systems (hardware) and processes including training of employees, 7) maintenance and optimization of IT-hardware, 8) data management (esp. handling of error messages), and 9) control and optimization of (logistic) processes.

Jobs with no or low qualification requirements (like machine operators) will become less important because they can be substituted by automated processes (Weber 2016). However, also in the future, there will remain manual or physical activities in the value chain that cannot be automated, either for technological or economic reasons (Spath et al. 2013). Jobs with medium qualifications will continue to be required but with different qualification profiles. Their main roles will be to oversee automated processes and get involved in case of problems. This aspect will become important in both initial as well as ongoing vocational training (Pfeiffer et al. 2016). One challenge to be addressed in this context is that in highly automated systems operators are relatively distant from the manufacturing steps which will make it more difficult to build up experience based knowledge to cope with non-routine issues in the production process. This is no new topic and was already raised during the 3rd industrial revolution as "ironies of automation" (Bainbridge 1983): operators of highly automated processes lose valuable cognitive expertise, required to solve non-routine issues, e.g. machine breakdowns. Relatively undisputed is the expectation that, driven by technological and system complexity, university educated positions will increase (Weber 2016). Overall, it can be expected that abilities to understand processes and abilities to solve problems in such processes will become more important in smart Industrie 4.0 factories (Hirsch-Kreinsen & Weyer 2014).

One approach to train employees in what are somewhat diffuse and highly context specific Industrie 4.0 skills is to simulate the conversion of low-automated or single-purpose-automated manufacturing environments to smart automation systems in so-called learning factories (Prinz et al. 2016; Blöchl & Schneider 2016). Another vital way may be to take the concept of blended-learning in higher education (Alammary et al. 2014) and apply it within a production context (Brosda et al. 2016). Going in a similar direction is to use augmented reality for initial and ongoing qualifications (Guo 2015).

To summarize, working on the right qualifications of employees who design, run, maintain and improve smart Industrie 4.0 production processes will be key critical for the success of such initiatives. We are only at the beginning to fully understand what this will require from leaders in Manufacturing and Human Resources.

Strategic Implications

While it is frequently mentioned that Industrie 4.0 will allow new and significantly different business models (Spath et al. 2013; Kagermann et al. 2011) only few publications explicitly raise the issue of integrating Industrie 4.0 with corporate strategy (Selim & Schumacher 2016; Hirsch-Kreinsen & Weyer 2014). This is somewhat surprising, given that the competitive landscape is likely to be mixed up significantly.

From a strategy formulation perspective, Porter's concept of sustainable competitive advantage defines three base strategies (Porter 1985): cost leadership, differentiation or focusing on a niche. Industrie 4.0 as a value creation concept has the potential to bring these core strategic positions much closer together, thus eliminating much of the comfort zones many companies make solid profits in.

With the ability to produce very small batches at close-to-mass-production cost large companies will break into niches they had previously decided not to address or weren't able to compete in because of high change over cost in conventional mass production systems. Niche producers are likely to suffer from this change in competitive focus.

By the same token, cost leaders in industries with physical flow production (not so much Chemical, for example) will likely lose a substantial portion of their competitive position. Differentiators will be able to match or come close to a cost leader position without losing their differentiation potential. While some cost leaders may be able to benefit from the possibilities to increase their level of differentiation by including personalized elements in their products, the authors view it more likely that differentiators will use Industrie 4.0 processes and technology to improve both their offer flexibility as well as their cost base. Cost leaders are likely to suffer from this change in competitive focus.

In any event, before starting to execute Industrie 4.0 initiatives, companies should test and, if required, adopt their business strategy in line with new opportunities, like additional services, new products or new markets to be served, as well as (competitive) threats that can be expected to show up in current markets by competitors which vertically or horizontally expand their value chain. From an implementation perspective, Industrie 4.0 strategies are very challenging. This is because strategy implementation has a task-oriented dimension - basically pulling together a plan, provide sufficient resources and monitor execution - as well as a behavioral dimension - making sure that people impacted by the change, accept and support the initiative (Kolks 1990). From a task-oriented perspective, Industrie 4.0 initiatives are complex projects, likely to impact the entire value chain of a company. Planning and managing content and execution of such a project is a challenge in itself.

However, in the behavioral dimension, it is important that people are both willing and able to act in line with their newly defined roles and responsibilities. Otherwise, motivating managers and employees to act as organizationally desired, will be very difficult to achieve (Porter & Lawler 1968).

Conclusions

Industrie 4.0 has the potential to change the way how business is going to be conducted in the future. While its roll-out will take some time and the competitive landscape will not change overnight, the rules of what drives industrial economic success will have to be adapted if not re-written. The authors suggest a simple framework of how to look at and analyze implications of Industrie 4.0. Numerous activities to develop and deploy required technologies are under way. Governments, large corporations, universities and research organizations drive this process with increasing momentum in many industrialized countries. However, little knowledge is available as of today how companies, especially SMEs, are supposed to approach this topic within the context of their strategic management activities.

While learning factories and knowledge platforms may help to solve the process issue of implementing Industrie 4.0 at the individual enterprise level, the authors recommend to study and develop guidelines which help companies to deal with the strategic dimension of the phenomenon.Even more important may be what kinds of qualification do employees in Industrie 4.0 production systems need to have, how do these compare to what is available in today's workforce, and what needs to be done to close the gap.

This paper gives some first ideas regarding the challenge. More research is required to provide answers that can be executed in real life situations.

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