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INDUSTRY 4.0 AND SUSTAINABILITY IMPACTS: CRITICAL DISCUSSION OF SUSTAINABILITY ASPECTS WITH A SPECIAL FOCUS ON FUTURE OF WORK AND ECOLOGICAL CONSEQUENCES

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ABSTACT: Today, manufacturing companies are confronted by a variety of external factors (small delivery units, high variety of products, shorter delivery times and product life cycles or high quality requirements) that makes the production process even more complicated. Due to this increase in complexity, an intuitive production planning is no longer possible. To counteract this problem new production approaches are essential. A recent approach, which is well discussed in theory and practice, is Industry 4.0. Industry 4.0 provides an approach in which physical production processes and information & communication technologies grow more closely together. Embedded systems, sensors, actuators, mobile devices and production facilities are able to communicate with each other via the internet. That allows all production processes to be transparent and easily influenced. This connection enables an easy response to the factors mentioned at the beginning; the production of lot size one is profitable, customer requirements can be met quickly and flexibly or quality requirements are easily implemented. Especially for small and medium-sized enterprises (SME), this can be a key success factor for (international) competitiveness. In addition to these economically measurable success factors it is important for companies to also consider environmental and social impacts (e.g. future of work, resource efficiency) to ensure durable competitiveness. To reflect these issues the objective of this paper is to discuss potential social and environmental impacts of Industry 4.0 with a focus on small and medium-sized enterprises and reference to an empirical study. To fulfill this objective, Industry 4.0 is defined theoretically at the beginning. This includes definitions and history of all industrial revolutions – from the 1st to the fourth. After this it will be discussed how this new approach can influence the social and environmental perspective of sustainability. In order to apply these theoretical aspects practically, the next chapter focuses on sustainability impacts based on Industry 4.0. This refers to current literature and an empirical study done within this field in Austria. Based on this, conclusions are made.
Keywords: Industry 4.0, small and medium-sized enterprises (SME), sustainability impacts

1. INTRODUCTION – INDUSTRY 4.0

”In a few decades time, computers will be interwoven into almost every industrial product.”

(Karl Steinbuch, a german computer science pioneer, 1966)

Global competition in the manufacturing engineering sector is more and more increasing. In addition, the United States and subsequently the German Industry have recognized the trend to deploy the Internet of Things and Services in Manufacturing Industry. The US are taking measures to combat deindustrialization through programs to promote advanced manufacturing [1].In Germany and Austria the term Industry 4.0 is nowadays almost used at Industry-related fairs, conferences and many calls for public founded projects. The frequently cited fourth industrial revolution seems within reach. However, what does Industry 4.0 exactly mean?

1.1. (R)Evolution Industry 4.0

The major idea of Industry 4.0 is the introduction of internet technologies into industry. Currently, industrial production is facing serious challenges, because information and communication technologies – e.g. the Internet of Things (IoT), Cyber-Physical Systems (CPS), Embedded Systems (ES) – are entering the factory. Industry 4.0 is an umbrella term, a vision that shows where the journey in industrial production is going. Many companies are already unconsciously on this trip by using individual components of Industry 4.0 concepts today. As shown in figure 1, industrialization began at the end of the 18th century with the introduction of mechanical production equipment, such as the mechanical loom for goods manufacturing. This first industrial revolution was followed by a second one at the end of the 19th century with the advent of electrically powered machinery used for mass production based on the division of work. The third industrial revolution then started in the early 1970s. It was based on the use of electronics and information technologies to automate production processes. In conjunction with constant miniaturization and the unstoppable advance of the Internet, ubiquitous computing has become reality. Microcomputers (embedded systems) are increasingly connected with each other and with the internet. These results in the convergence of the physical world and the virtual world (cyber world) to so-called cyber-physical systems; the enabler of the fourth industrial revolution [2,3]. The term Industry 4.0 (in the US the term industrial internet or integrated industry [4]) is made conventional.

Two fundamental approaches are cited to enable Industry 4.0 in future: cyber-physical systems are integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. Cyber-physical systems represent the further evolutionary stage from existing embedded systems and build the basis of an internet of things, which combines with the internet of services to make Industry 4.0 possible. The internet of things – the next generation of the internet – is a global system of IP-connected computer networks, sensors, actuators, machines, and devices. Merging this physical world with the virtual world of the internet and software enables companies and consumers to create and enjoy new services that are founded on web-based business models. This will have a big impact on the way we do business [5,6,7,8,9].

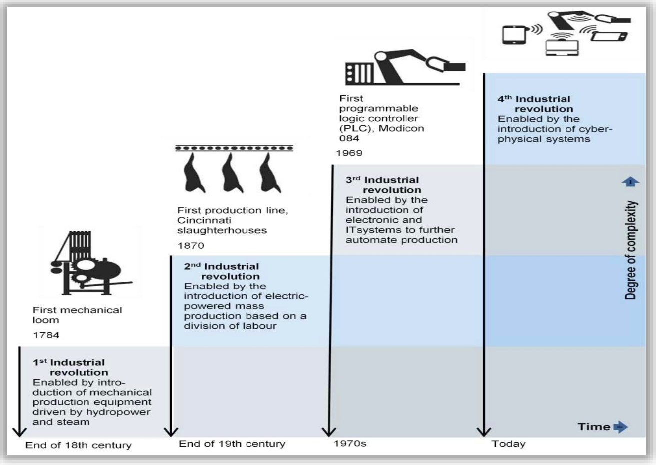

Figure 1 – Stages of the Industrial Revolution [3]

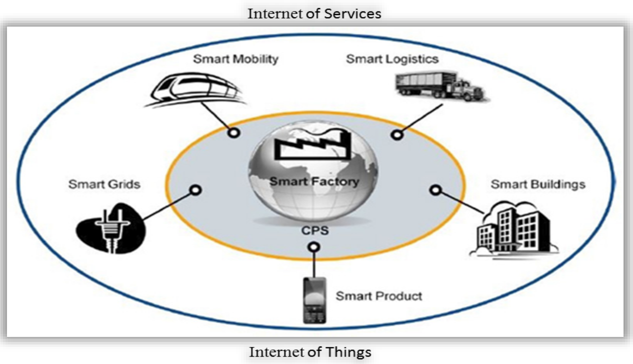

Figure 2 – Industry 4.0 and smart factories as part of the Internet of Things and Services [2]

1.2. Smart factory

Industry 4.0 focuses on smart products, procedures and processes. A core element of Industry 4.0 is therefore the smart factory as shown in figure 2. The smart factory supports the fast-growing complexity and efficiency in production. In the smart factory there is direct communication between people, machines, conveying and storage systems as well as production facilities. Smart products know their manufacturing process and future applications. With this knowledge, they actively support the production process and the documentation ("when was I made, which parameters should be used to produce me, where should I be delivered to?").Industry 4.0 represents a paradigm change from "centralized" to "decentralized" production – made possible by technological progress, which constitute a reversal of conventional production process logic. This means, that industrial production machinery no longer simply processes the product, but that the product communicates with the machinery to tell it exactly what to do [9]. With its interfaces to smart mobility, smart logistics, smart buildings and smart grids the smart factory is an important element of future smart infrastructures. Conventional value chains will be refined and new business models will become established [2,3,10]. In the past, industrial revolutions usually had a growing affluence. They also typically have had comprehensive social and environmental consequences – both positive and negative. The next chapter examines the social and ecological impacts of Industry 4.0.

2. SUSTAINABILITY IMPACTS

Basically, the main objective of Industry 4.0 is to strengthen and expand the long-term competitiveness of the company by increasing flexibility and efficiency of the production through communication, information and intelligence. Like the three upstream steps of the 4th industrial revolution (alias Industry 4.0) leads to impacts within (e.g. on production factors technology, organization and employees) but also outside the company (e.g. on the social and ecological environment). Taking a closer look at literature it can be seen, that especially the impact on future work as well as the impact on the environment are discussed intensively.

2.1 Future of work

Experts agree that despite the higher degree of automation people shall still play an important role in Industry 4.0. Within the empirical study production work of the future[1] 60.2% of respondents stated that human work still will play a very important role in future production. Further 36,6% ascribed human work an important role. In Industry 4.0 will still be classic manually running processes that have to be accomplished adequately by skills of people such as intelligence, creativity, empathy or flexibility. However, the positioning of people within the production and the tasks they have to be performed will change [14,15]. SPATH describe this change as follows "In the production of the future people are more conductors and the coordinators of the factory. Hard muscular work and also a part of the mental work is done by machines" [14, p. 48]. The strong network of people and machines within Industry 4.0 has the consequence that job content, work processes, work environment and the required skills need to be changed significantly. Because of this, also new professions for employees will emerge [16,17]. As physical tasks will be less relevant in future, expertise in the field of new communication technologies, in terms of planning, execution and decision-making processes, control or programming or in the fault and error correction are becoming increasingly important [18,19,20]. In addition, demand for interdisciplinary knowledge and skills to understand working and thinking corresponding disciplines and faculties become more important [20,21].

Due to the increasing level of automation and networking between people and machines, the physical strain on people will drop. This is particularly advantageous, since the proportion of older workers will increase due to the age shift. Thus, employment opportunities especially for older workers are improving. Parallel to the declining physical demands, greater psychological stress (emotional and mental) is expected. On the one hand this is caused by the constant change in work content and hence required increasing flexibility and responsiveness. On the other hand, it leads to emotional stress, if communication and cooperation between employees is diminished by increasing interaction between humans and machines or if allocation of work no longer emanates from supervisor but from a technical system. Already today it can be seen that the number of sickness days due to psychological stress is on the rise. This could be exacerbated by Industry 4.0. Therefore, it is important to consider this risk already in the conception of Industry 4.0 [21,18].

Although the increase in flexibility can lead to greater psychological stress, it could have simultaneously positive aspects concerning employees' work-life balance. Thus, the work organization can be better adapted to the needs of employees in terms of reconciliation of work and private life. Also, personal and professional development can be better combined [21,18]. This advantage can be especially for SMEs crucial in future to counteract the shortage of skilled workers. Empirical studies predict that there will be a shortage of skilled worker in German-speaking countries due to the demographic situation. Especially for SMEs, it is becoming more difficult to find qualified employees and to retain them in the long term [23]. Thus, the described advantages of Industry 4.0 can provide a competitive advantage in the fight for employees.

In summary, it should be noted statements about quantitative effects of Industry 4.0 on the number of employees from today's perspective are hardly possible yet. However, it is assumed that there will be a decline from simple manual tasks. For the affected group of employees an appropriate professional development towards Industry 4.0 has to be considered in time. Otherwise, this can lead to social problems [20]. From the qualitative point of view, it can be already seen that professions and skills of production employees will change. At this point, in addition to manufacturing companies also educational institutions are asked to think already on required training of the future.

[1] Empirical survey of 661 companies and 21 Industry 4.0experts.

2.2 Ecological consequences

Production places a strain on the environment in many ways. In addition to the desired value added also a variety of undesirable side effects (e.g. consumption of natural resources, energy consumption, emissions, waste ...) are created which can lead to environmental damage. In Europe, there have been many attempts several years to limit these negative effects which cause challenges for industry. Adherence to high environmental standards, today's and future emission trading scheme, CO2 reduction targets or raw material and energy price trends are just a few examples that increasingly influence the competitiveness of production companies. A high raw material and energy consumption within the industrial production results not only in high cost, but also increasingly environmental and supply risks entails. A major aim represents energy and resource efficiency which is mainly determined by the production of the company. Accordingly, energy- and resource-efficient systems will become more important [24,25].

Industry 4.0 can provide support through continuous energy and resource management. By providing detailed information on each point of the production process, resource and energy use can be optimized over the entire value network (this means optimal resource and energy productivity, optimal resource and energy efficiency). In addition, systems can be optimized continuously during production process in terms of resources and energy consumption or emission output. This can make a substantial contribution to the sustainable development of the company. It is also possible to consider resource and energy efficiency already in the planning stage of the company by the optimization of rooms, spaces, pathways or lines, by the design of centralized and decentralized supply and disposal systems or by creating closed material and energy cycles [18].

The optimization of the industrial production process can lead to a reduction of CO2-emissions. These lower emission levels facilitates to building factories increasingly in urban areas. Such urban production provides in addition to social (increase of work-life balance) environmental benefits (e.g. minimization of emissions by daily commuting to work) [21].

By rising documentation within Industry 4.0 the final disposal of products or equipment will also be simplified. Through collected information even the most complex technical devices can be decomposed into its components at low cost and, subsequently, disposed or recycled. Technologically complex recovery methods make it possible to close and optimize material cycles. This enables an efficient cost reduction associated with effective contribution to the careful use of resources [21]. Production of future is often discussed in combination with new manufacturing technologies. Experts believe that additive manufacturing technologies such as 3D printing play a special role. This manufacturing technology enables the production of items with specific properties built on a layer-by-layer basis. Different materials are used for 3D-printing, e.g. ceramics, plastics, gypsum or metals. 3D-printing is particularly suitable for the production of unique pieces or small series (e.g. prototypes, replacement parts or highly specialized products). 3D printing is considered as an environmentally friendly production technology, because fewer resources are required, waste is hardly generated or production and transport logistics can reduced by decentralization [26,27,28,29].

In order to apply theoretical aspects practically, the next chapter focus on the status of digital production (premise for Industry 4.0). This will be done with reference to an empirical investigation made in Austria.

3. EMPIRICAL INVESTIGATION

What does Industry 4.0 mean for the software sector? In the area of production, automation engineering as well as information technology; vertical IT-Integration refers to the integration of the various IT-Systems at the different hierarchical levels (e.g. actuators and sensors on the shop floor, Manufacturing Execution Systems in production management and ERP-Systems on the corporate planning level). Without high quality master and transaction data, clear IT-based processes and the ability to complex data analysis, Industry 4.0 is not possible. The following statements examine the status of Digital Production – as a prerequisite for Industry 4.0 –in Austria. Approximately 99.6% of Austrian companies are small and medium-sized enterprises (SME) with 250 or less employees [11]. The Institute of Industrial Management FH JOANNEUM Kapfenberg/Austria did an investigation about the situation of digital production (Smart Production) with focus on SME. From 4725 questionnaires which were sent out to SME and 222 returned responses, 136 records were used for evaluation. Figure 3 illustrates, that digital production currently has a low penetration in Austrian small and medium enterprises. ERP- and

MES-Systems are common used in large companies, but rarely in SME (ERP 46%, MES 7%). It must be noted, that there is a lack of software support and vertical IT-Integration in SME and paper-based information exchange dominates.

The second part of the study focused on MES provider from Austria and Germany, because the number of Austrian MES providers is restricted. Throughout all future trends were considered as very important or important. Surveyed MES providers suggest a clear trend towards "full IT-Integration", "green production" and "plug and work Integration of new or modified machines in an existing IT-landscape" (Figure 4).

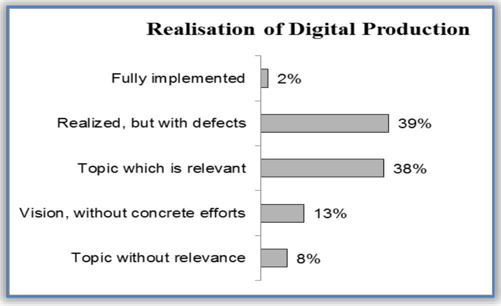

Figure 3 – Digital Production in Austrian Small and Medium sized Enterprises (n=136) [12]

In addition to these basic results, also findings regarding sustainability can be drawn from the study. The continuing important role of human being in Industry 4.0 has already been discussed in detail previously. This is also confirmed by the results of the study. A large majority of respondents see people as the crucial success factor in the implementation of IT systems. This result can be passed on Industry 4.0 as well, since both the technical know-how of the employees, the leadership-skills of the board as well as the composition of the project team are essential for success [12].

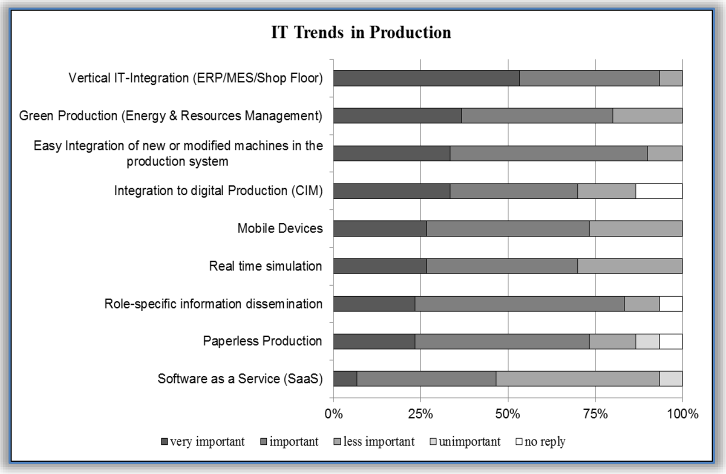

Figure 4 – Future Trends of Digital Production (n=30) [12]

The study shows that green production in general and energy and resource management in particular has already for almost 45 % of the surveyed company's high priority. The implementation of an energy and resource management as part of Industry 4.0 is thereby consistently perceived as positive. In addition to the transparency of the energy input, also the possible allocation of energy costs to products, process steps or departments is regarded as positive. In addition, the surveyed companies believe that the topic Green Production will be increasingly important in future [12].

A transnational study conducted by CSC-Computer Services Consulting also shows similar sobering results. More than half of the managers interviewed in Austria, Germany and Switzerland do not know the term Industry 4.0. Only a quarter knows accurately about the changes associated with Industry 4.0. Nevertheless only 13 % of the surveyed companies in Austria consider implementing training or education programs in this area. 84 % are not informed enough about the risks and opportunities of Industry 4.0. The expected improvements resulting from Industrial 4.0 include greater efficiency (50%), cost reduction (43%) and increased productivity (40%), customer satisfaction (40%) and increased competitiveness (39%) [13].

4. SUMMARY

Industry 4.0 represents a fundamental paradigm shift towards decentralized and individualized production, which will enable new, internet-based services and business models. Industry 4.0 is characterized by networking and the internet. Traditional supply chains will evolve into highly adaptive supply networks. Small and midsize companies will play an important role in such value-add networks. As a result, Industry 4.0 can be a solution for the challenges of the future. Austrians manufacturing landscape is characterized by a large number of small and medium-sized enterprises which often produce highly innovative products in an international environment.

The results of the literature review and empirical study show that Industry 4.0 offers numerous opportunities for companies. Especially in a high-wage country like Austria increased automation can provide a competitive advantage. At the same time environmental challenges can be easily accomplished. Especially for SMEs Industry 4.0 entails USPs in international competition like lot size one, rapid response to customer, high quality and flexibility. Also impacts on labor market can be seen diverse. In addition to the disadvantages already discussed Industry 4.0 can be seen as a chance within the battle for skilled professionals.

In some manufacturing companies first steps of Industry 4.0 are already done, but the path towards Industry 4.0 is an evolutionary and not a revolutionary process. Information-, automation and production technologies will be more intertwined than ever before. Networking is not only a goal; it is an absolute requirement for Industry 4.0. However, Continuous IT-Networking – as a prerequisite for Industry 4.0 – hardly exists in Austrian small and medium-sized enterprises. Approaches of the Industry 4.0 already exist; until full implementation, it will probably take a long time. Experts disagree and talk about a period of up to 20 years.

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