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What benefits do initiatives such as Industry 4.0 offer for production locations in high-wage countries?

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Abstract

According to claims made by the proponents of initiatives such as Industry 4.0, information technologies will in the future play a substantially more significant role in production processes both for the service sector and for the production of physical goods than they do today. This paper starts by discussing the origins, essence and expectations of initiatives such as Industry 4.0. It then proceeds to outline concepts and examples around such initiatives. Finally, it offers a realistic view of the likely future effects. The paper has a special focus on examples in Switzerland.

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Keywords: Industrie 4.0; production processes; Switzerland

1. The origins, essence and expectations of initiatives such as Industry 4.0

The term *Industry 4.0* was coined by Acatech, the German Academy of Science and Engineering. They set up a working group in 2011 as part of the response to the American "cyber-physical systems" initiative, and their report was published in 2013 [1, 2]. It postulates a fourth industrial revolution, following on from the previous revolutions of mechanization, electrification, and computerization. As early as 2012, it was receiving widespread support from the German government and in scientific circles, reflecting the fact that it had become a concerted initiative [3]. Leadership in this area came from both the political and scientific arenas. Significant financial resources were (and continue to be) made available by the German federal government, by the German states, by the BMBF (Germany's Federal Ministry of Education and Research) and the DFG (German Research Foundation) to finance ongoing work by German research institutes and by industry. The initiative is also fully supported by employers' associations [4].

This digital revolution should replace many production technologies that have been used until now, and should do so in a disruptive manner, as happened within a very short time in the second half of the 1990s when digital photography came in. At the same time, individualization of products to customers' requirements will become more widespread, without significantly increasing costs. The aim is full digitization of production technology, resulting in a "smart factory": products and production systems will become (more) intelligent, which means more versatile, more efficient, more ergonomic, with better integration throughout the entire supply chain – right to the customer. And they will make decisions autonomously, as decentralized as possible. The claim that this initiative is a "revolution" is openly stated in advance, in contrast to the first, second and third industrial revolutions, which were only recognized as being revolutions after the event.

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The term CPS "cyber-physical systems" was first used in the USA between 2006 and 2009. It was initially an initiative sponsored by the National Science Foundation (NSF) [5, 6]. In a CPS, information technology devices which control physical objects (e.g. mechanical and electronic objects) work together over a communication network. Key building blocks for this sort of system include concepts like intelligent sensors, the Internet of Things, big data as well as technologies of additive manufacturing or medical engineering. In industry, the trend is increasingly towards a complete network that covers all of the relevant machines, both within a company and across companies, and regardless of the machine's manufacturer. The digital components should allow automated production to adapt increasingly quickly to changing requirements.

A prerequisite for CPS is a very high degree of standardization. In the USA, a first step in this direction was taken in 2014 when the *Industrial Internet Consortium* (IIC) was founded. Many large companies work together in this organization to draw up common standards, which facilitates interoperability between systems [7]. Since also Industry 4.0 cannot be implemented without these common standards, the "Plattform *Industrie 4.0*" initiative was set up in Germany [8].

In 2015, Japan responded by launching a largely industry-led initiative called IVI, "Industrial Value Chain Initiative" [9]. It was accepted that the way in which standardization occurs is the key for economic success. So one of the aims of the IVI is to create common standards for technologies that can connect factories, and to internationalize Japanese industrial standards.

In Switzerland, four industry associations responded by launching the "Industrie2025" initiative in 2015 [10]. It is closely modelled on Industry 4.0. The name underlines the long-term aspect of the transformation process, which is supposed to be a rather continuous process. Due to Switzerland's political system and regulatory policy, there is no government-supported program like Germany's Industrie 4.0. For many years, the CTI (Commission for Technology and Innovation) of the Federal Department of Economic Affairs, Education and Research has supported industry-led research projects with universities, universities of applied sciences and colleges. In such projects, the CTI finances the salaries and expenses of the academic personnel, while the companies have to cover their costs themselves. Between 2017 and 2020, the CTI is also supporting two National Thematic Networks in the CPS field: Additive Manufacturing – AM Network, and Swiss Alliance for Data-Intensive Services (data + services) [11].

To keep this article as concise as possible for readers with practical experience, we will not provide a full list of previously published literature here. [12] contains a larger selection of publications, with a focus on contributions from Germany.

2. Concepts and examples around Industry 4.0

Companies expect that, finally, the benefit of initiatives such as Industry 4.0 will be a contribution to the company's net profit. Drivers for this include new products that address customers' needs, and more effective and more efficient processes in R&D and production.

For many years now, and especially in high-wage countries, standardization and automation have been at the forefront of all industrial initiatives, since they are the two key components of industrialization. If an initiative is successful, it leads to an increase in effectiveness as well as efficiency. In this respect, initiatives in the classical industries sector, i.e. the production of physical goods, behave in the same way as initiatives in the service sector [13]. Digitization in the context of initiatives such as CPS, Industry 4.0, IVI or Industrie2025 often involves both sectors. The contribution in [14] contains a comprehensive discussion of CPS in manufacturing, but also looking into the service sector. The following examples from the various key building blocks discussed in Section 1 also often involve both sectors. Most of the examples in this and the following Section are taken from the Swiss industrial and services sectors. They broadly meet the aims of initiatives like Industry 4.0 discussed in Section 1, namely (1) individualization of products, (2) full digitization of production technology along the supply chain, and (3) autonomous decision making in decentralized product and production systems.

2.1. Smart Sensors

Apart from simply measuring things (as a conventional sensor would), a *Smart Sensor* can also process the measured data and make the results available in the required form. The (decentralized) "intelligence" is provided by a microprocessor. Here again, the driving force is the need for individualized production. Figure 1 shows some examples, including accelerometers, motion sensors and magnetic field sensors for functional movement therapy [15].

Fig. 1. An example of a smart sensor. Valedo sensor. (Source: Hocoma)

The use of sensor technology helps improve accuracy in the observation of the patients' movements. In a fully digitized way, the data collection results can be processed by the sensor, and converted to movement objectives that are tailored for the patient and which can be displayed on a mirror, for example.

2.2. Internet of Things (IOT) and Big Data

The *Internet of Things* is a network of material or non-material goods or objects ("things") that are connected to each other and that can exchange data. An integrated computer identifies each "Thing" and can communicate via the Internet infrastructure [16]. As a sensor, or with the help of a sensor, the "Thing" can capture useful data, which it can then autonomously and in a fully digitized way send on to other interested objects, either humans or machines. One example would be Internet-based building management systems (e.g., light, temperature, and humidity) that are adapted to each individual resident. The postulate is that the Internet of Things also allows large volumes of data to be gathered from remote locations, which in turn enables big data. The Kizy tracker shown in Fig. 2 is an example [17].

Fig. 2. The Kizy tracker (Source: Kizy Tracking)

Kizy Tracking uses a small tracker (the device measures just 10x5x0.8 cm) connected to the mobile phone network. That reduces the accuracy of the position tracking, but it also reduces the cost and the power consumption. When specifically tracked by the user, it can be accurate to within 100 meters. An online tracking platform allows users to check the position of any carrier (e.g. container, box, pallet) that contains such a tracker at the push of a button. Depending on how often the position is tracked, the device can operate autonomously for up to two years. The tracking system costs just 20 Swiss cents (actually nearly equal to 20 US cents) per day for each carrier, i.e. each tracker.

Big data is a term for data sets that are so large or complex that traditional data processing applications are unable to capture, store, and process them [18]. The term is thus relative to technologies that are currently used, and like several other terms in this article, it appears to be more of a postulate than a reality at the moment. It is often applied to “advanced” methods of evaluating data with the aim of improving decision making, which in turn reduces risk or increases efficiency. The idea is that the large volumes of data will allow statistical analysis to identify previously unknown correlations and trends. One example would be maintenance systems for machines [19]. Tasks that are more complex can be found both in physical systems (e.g., meteorology, environmental research) and in socio-technical systems (e.g., businesses, government). Data protection is an important issue here [20].

2.3. Additive manufacturing

Additive Manufacturing (AM) is nowadays more widely known as *3D printing* (although, in doing so, there is actually no printing involved). It is a process that offers the possibility of creating three-dimensional objects. A 3D model created by CAD software can be used to produce an item by building up successive layers of a material (plastic or metal).

A first benefit of this process lies in being able to produce far more complex components than were feasible before, particularly with concealed geometries which are not suitable for either drilling or milling. A second benefit of this process lies in the efficiency and speed with which the first item of a production batch can be produced: The interface from digital design files to manufacturing is seamless, which corresponds to the aim of full digitization along the supply chain. In fact, the slow, expensive mould-making process is no longer needed. That means this process is well-suited to making prototypes. Conventional (e.g., abrasive) methods may still be more cost-effective for mass production, even assuming that they are not a necessity for quality reasons. A third benefit is that the lot size “1” can be produced cheaply, which is a decisive factor in individualizing products. Totally different 3D shapes can even be produced in a container, i.e., in a single production batch. This makes the process attractive for spare parts. Again, the process has to provide sufficiently high quality. Identifying the optimum arrangement needs an algorithm, in much the same way as a cutting optimizer is needed for 2D cutting, such as when using a laser cutting machine to trim sheet metal. The use of 3D printing to make toys in the private sector underlines 3D printing's potential for personalized production. [21] is the best-known 3D modelling platform in the German-speaking countries. It contains comprehensive information about the various different AM processes, and cost estimates for a "Buy" scenario [22]. [23] and [24] demonstrate that product designs suitable for AM are important for the future. [21] and [23] also contain numerous showcase examples from Switzerland. Fig. 3 contains an example, featuring spare parts.

Fig. 3. "Digital" spare parts for textile machinery (Source: 3D Prints Lechthaler Reinhard)

Additive manufacturing is already being used as a solution for spare parts where the moulds used for injection moulding no longer exist. The company made prototypes, and then 900 series production parts that were optimized for AM.

A very actual AM application is medical technology, in the form of biocompatible products [25]. Fig. 4 shows an example.

Fig. 4. Incision template for maxillofacial surgery (Source: Composites Busch SA)

This template is used in a "reconstruction of a lower jaw bone with an autologous fibula bone graft". The incision template "ensures that the necessary osteotomy on the patient's fibula is performed exactly as planned".

2.4. Personalized medication

Personalized medication is a patient-focused approach that incorporates both medication and the dispensing process. This is an important concept for health care of the future. The processes rely heavily on the use of various information technologies. In the case of solid forms (e.g., tablets), this can involve automatically dividing the blister packs up into individual doses and packing the different individual doses according the patient's prescription for delivery to the patient at the appropriate time, with integrated tracking and tracing. For liquids, it involves the automatic production, tailored to the patient, of liquid medicines (e.g., for cancer treatment), again organized by date and time for delivery to the patient and, if necessary, with an appropriate *cold chain*, i.e., an end-to-end cooling system for transport from the manufacturer to the consumer.

Figure 5 shows a component for high-precision distribution of liquids. The component is digitized and produced using 3D printing.

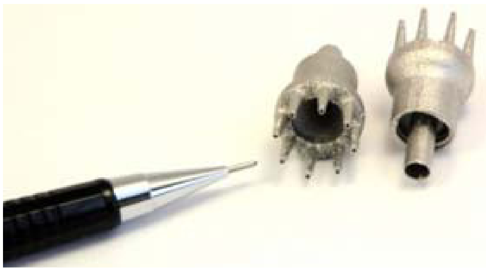

Fig. 5. High-precision distribution of liquids (Source: 3D Precision SA)

The component was designed for a medical laboratory, and is used to fill eight small bottles at the same time, equally and with repeatable precision.

And one final thought: 3D printing could in the future be used to produce biomedical fibre [26] for making pills that are individualized, that is specifically designed for a patient and "that can release drugs with any desired release profiles" [27].

3. A realistic view of the impact of Industry 4.0

In terms of the *medium-term* impact of Industry 4.0, the examples given above show that, in practice, overall development of digitization tends to be a rather continuous progression. However, companies that are built around specific analogue technologies, such as Kodak or the Swiss firm Gretag in the classical (today also called "analogue") photography sector, are exposed to substantial risk [28]. The same would also apply, for example, to companies that currently offer product lines for analogue telephony, which will be replaced by VoIP relatively quickly.

Another sector is offset printing, which is constantly losing ground to digital printing. With digital printing, many of the steps relating to setting the copy (i.e., the printing plate) are no longer necessary. That significantly shortens the production process, and it is possible to print something different on each sheet in a short space of time (the keyword being "personalized prints"). Fig. 6 shows a real, since 2015 working example of a printing machine that is 48 m long and 8.9 m wide, and weighs 101 t. The machine is used to print packaging, and has 120,000 fixed ink-jet nozzles. Its highest print resolution is 600x900 dpi, and it can handle sheet sizes of 2100 x 1244 mm at a speed of 200 m/min.

Fig. 6. Large-scale digital printing at high speed (Source: Model AG)

For the packaging company, it has been a real revolution: quicker set-up times, small, precisely deliverable production volumes, fast short-run follow-up orders, (virtually) no waste [29].

Another area where production technology has already been successfully digitized is digital tooth imprints. A 3D model of the teeth and a bite simulation can be digitally produced. The control model is produced using 3D printing.

Finally, we must also mention building automation, with a trend towards "intelligent living". Digitization can use intelligent sensors to automatically, and on a user-specific basis, provide energy-saving lighting and temperature control, for example.

However – and this is the key thing to note from these examples – all of these technological developments happened without initiatives such as Industry 4.0, and they will continue to happen in the future. What does that mean? Viewed across all sectors and technologies, over the *medium term*, ongoing digitization over the next few years will continue to be a progressive process, rather than a revolutionary, disruptive one. Nevertheless, as we have seen, for *some* sectors and *some* technologies, change can occur very quickly, and can be very disruptive.

Over the *long term*, though, the outlook is very different. In terms of global competitiveness, initiatives such as Industry 4.0 offer significant benefits for production locations in high-wage countries.

A first scenario relates to the degree of success in establishing common standards for technologies that can connect factories. As discussed in Section 1, various initiatives are already underway in this context. Innovation based on improved standardization and automation enables companies to keep their production locations in their own (high-wage) countries by using new technologies to manufacture products only in that country for a period of time. One example of this is hybrid technology in the car industry, where for example

Toyota for many years made all the new components in Japan. The same applies to standardization relating to digital products and production systems, and particularly to their inter-operability. Basic technologies such as for instance LoRaWAN [30] exist already.

A second scenario relates to the qualified workers and managers that are needed to implement initiatives such as Industry 4.0. In Germany, the government's full, concerted support for Industry 4.0 at both national and regional level has significantly enhanced the status of all who are involved. Industrial production has benefited very considerably from it, as has the extent to which information technology has been integrated into industrial production, both in comparison with other branches of German industry and when compared with production in other countries. One consequence is that many talented young people, far more than today, are keen to work in industrial production again. In that respect, Industry 4.0 is above all an investment in the *long-term* future of production locations in high-wage countries. After all, it is precisely this group of talented young people who will take decisions about developing new products that will be in use from 2030 onwards. The best people will tend to develop and produce the best products, which in turn offers a competitive edge.

It is the author's view that these two long-term effects will mainly determine the benefit of initiatives such as Industry 4.0. The challenges linked with the second scenario are, however, all too often overlooked in the short-term hype surrounding the buzzword. This begs the question of whether this might not be, at least in part, because some of the key players are themselves so focused on short-term results.

4. Conclusion

This article shows the importance of industrial initiatives such as Industry 4.0. High-income countries in particular (e.g. USA, German and Japan, Switzerland) are looking to enhance their positions as production locations through the use of CPS (cyber-physical systems), Industry 4.0, IVI (Industrial Value Chain Initiative), or Industrie2025. The article outlines some of the concepts covered by these initiatives, and gives specific examples of products that are being developed and produced in Switzerland. Whilst technological developments across all sectors and technologies will be rather continuous over the medium term, digitalization means that disruptive effects may occur in some sectors and technologies, which means companies must keep a close eye on their situation. In the long term, such initiatives may give countries a competitive edge, because countries are already seeing their status enhanced by these initiatives, which in turn helps them attract the best young talent to their industrial sectors.

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