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Smart factories – the product of Indrusty 4.0

Abstract

In order to achieve efficient data transfer and improved production management, the industry has evolved into its fourth stage, into Industry 4.0. The key factor in this evolution is the introduction of IoT. Rapid information exchange between identification systems, smart control units and implementation systems have been enabled by IoT, thus creating foundations for smart material flow which is one of the crucial features of smart factories. In this paper, the main links of Industry 4.0 are described. The functioning of smart factories will be described, and we will include a list of traditional production processes which can be upgraded to the smart level.

Keywords: Industry 4.0, IoT, smart factory, smart data flow

Introduction

Industry 4.0, the Fourth Industrial Revolution, is currently going on. So, we have already undergone three industrial revolutions (Benotsmane–Dudás–Kovács 2018):

- Industry 1.0 – The First Industrial Revolution began in the 18th century with the use of steam power and mechanisation of production. Where thread was produced on a simple spinning wheel, the mechanised version achieved eight times the volume in the same time. The power of steam was already known to people, and its use for industrial purposes was the most significant breakthrough

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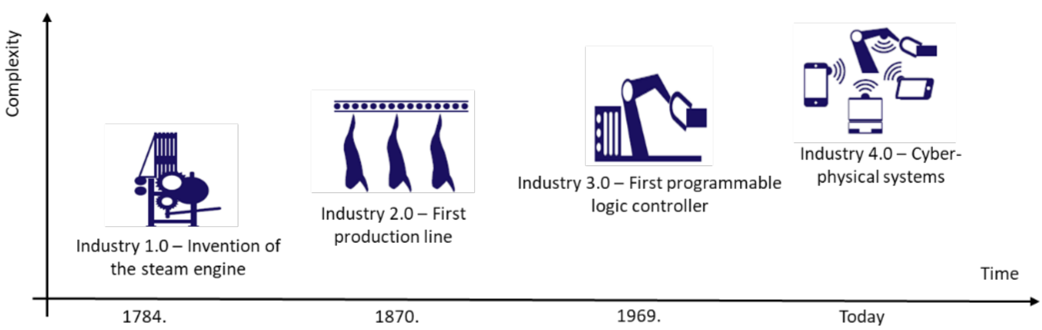
in increasing human productivity. As opposed to handlooms powered by human muscle, steam-engine powered ones were way more productive. Developments such as the steamship or (some 100 years later) the steam-powered locomotive brought about further massive changes because humans and goods could move great distances in fewer hours.

- Industry 2.0 – The Second Industrial Revolution began in the 19th century with the discovery of electricity and assembly line production. Henry Ford (1863–1947) took the idea of mass production from a slaughterhouse in Chicago: The pigs hung from conveyor belts, and each butcher performed only a single part of the task of in the butchering of the animal. Henry Ford transplanted this principle into automobile production and drastically altered it in the process. While before one station assembled an entire automobile, now the vehicles were produced in steps on the conveyor belt - significantly faster and at a lower cost.
- Industry 3.0 – The Third Industrial Revolution began in the 70s in the 20th century with partial automation using memory-programmable controls and computers. Since the introduction of these technologies, we have been able to automate entire production processes - without human assistance. Known examples of this are robots that perform programmed sequences without human intervention.
- Industry 4.0 – represents the industry which consists of full production automation, independent data exchange, cloud data sharing and storing, robots, AI (artificial intelligence), IoT (Internet of Things). It connects systems that used to be separate: IT (information technology) engineering and OT (operational technology) engineering. By combining them, a unique, autonomous system is created which is not dependent on humankind. Industry 4.0 makes production smart.

Figure 1: *Stages of the industrial revolutions*



Industry 4.0 & IoT

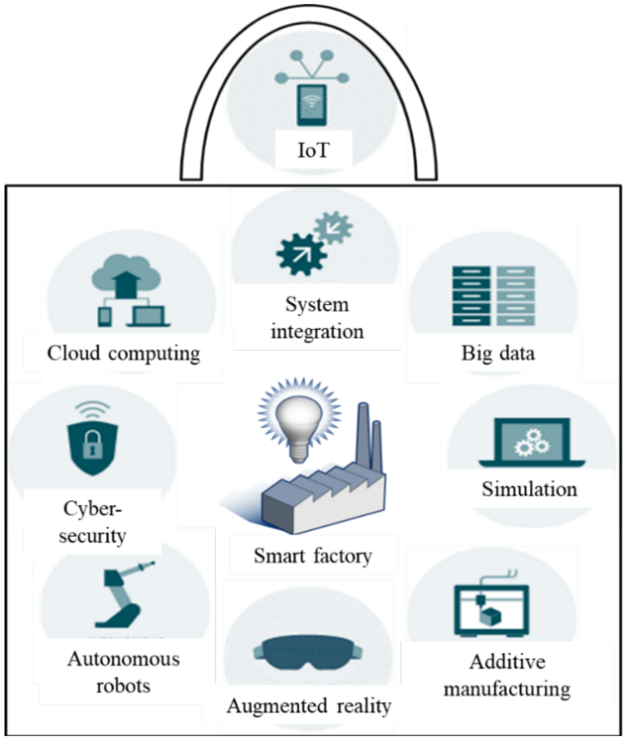
Industry 4.0 is a platform combining a variety of advanced modern technologies to meet today's challenges. Industry 4.0 elements are increasingly emerging as one of the main strategic management goals in recent years. The use of new technologies requires long-term, strategic investments intended to increase the competitiveness of enterprises in the future (Vrchota–Pech 2019).

Industry 4.0 is now unanimously considered the "fourth industrial revolution". This profound transformation of the way goods are produced, the service market is linked to the manufacturing sector, and innovative products are created has been in progress for some time now. In more operational terms, Industry 4.0 involves the organisation of production processes based on technology and devices capable of autonomously communicating with each other along the value chain, i.e. a smart factory model, where computer-controlled systems manage physical processes, creating a virtual and parallel world to the physical one. By attempting to simplify work, factories should become cyber-physical places, where the real world and the digital world are integrated. Production, as it has long been imagined, will include direct machine to machine (M2M) interaction as well as "man-machine" interaction. At the same time, new technologies will integrate objects, transforming them into intercommunicating systems with "intelligence" (de Candia 2019).

Historically, technological improvements that developed the production process were one of the most decisive in industrial revolutions. Recently, it has been suggested that the last stage production technologies have reached points to a new industrial revolution, which means it is Industry 4.0- i.e. the fourth industrial revolution. The usage of advanced technologies such as artificial intelligence, nanotechnology, quantum computing, synthetic biology and robotics in the industry is regarded as the beginning of Industry 4.0 (Görmüş 2019).

The easiest way to define Industry 4.0 is to describe its product – the smart factory. Within smart factories, the production is performed by robots and robotised machine tools. They communicate via IoT; they make decisions on their own and keep data in clouds. Data is stored on a remote server. Cloud storage has many incomparable advantages to traditional storage, whenever and wherever data access is possible, there is also on-demand resource deployment, etc. However, Industry 4.0 transcends simple factories. Industry 4.0 covers complete production systems, from the energy needed for operations, through logistics to resource management. Industry 4.0 represents the integration and digitalisation of all systems and subsystems essential for production.

Figure 2: *Components of Industry 4.0*



IoT is the key component of Industry 4.0. It provides the possibility to connect through a network all elements of a production system. It enables centralised control of all systems without a physical connection. It also provides an opportunity for the components of the system to communicate (Gubán–Kovács 2017).

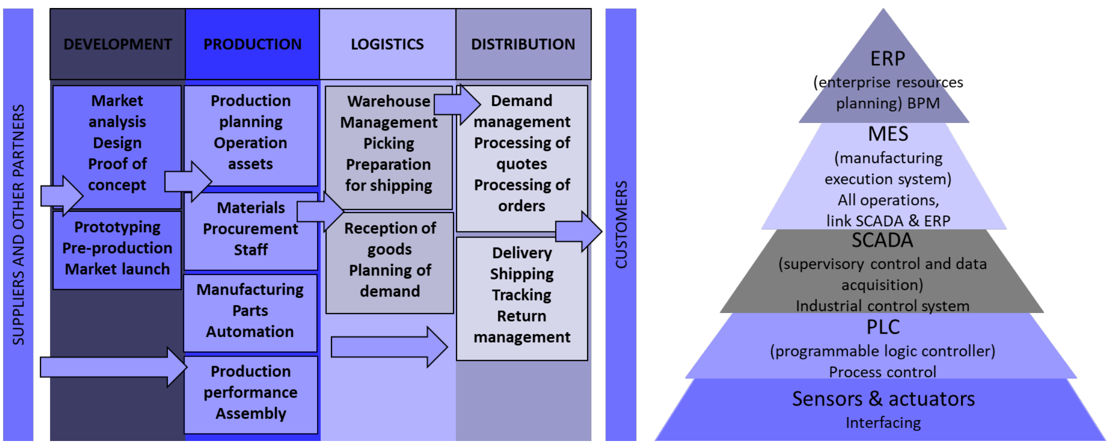
Horizontal and vertical production integration

One of the key features of Industry 4.0 concerning digital supply networks are horizontal and vertical production integrations.

Horizontal integration means networking all participants that are included in the creation of a product. The goal is to upload all relevant information in the cloud so that communication is autonomous. The idea is to eliminate the human factor as much as possible. Horizontal integration is shown in the next example:

The idea for a new product emerges based on digital surveys. The human task is to work out the idea and upload it to the cloud where it is available for the IT systems. The IT system creates an online marketing campaign which targets people and based on the reactions, the first orders arrive. At this step, human influence ends. The IT system starts to procure the raw materials and organises their transport and warehousing. Then the system demands new equipment if necessary, allocates tasks to the robotised tools and stores all data in the cloud. Later, the system organises the warehousing of the new products and their transportation to the customers by autonomous guided vehicles (AGV). The goal is to achieve greater efficiency with minimal cost. By integrating AI, IoT, cloud, material flow simulation, energy and money, exceptional profit can be realised.

Figure 3: *Horizontal and vertical production integration*



On the other hand, vertical integration represents the integration of data and IT systems during production processes.

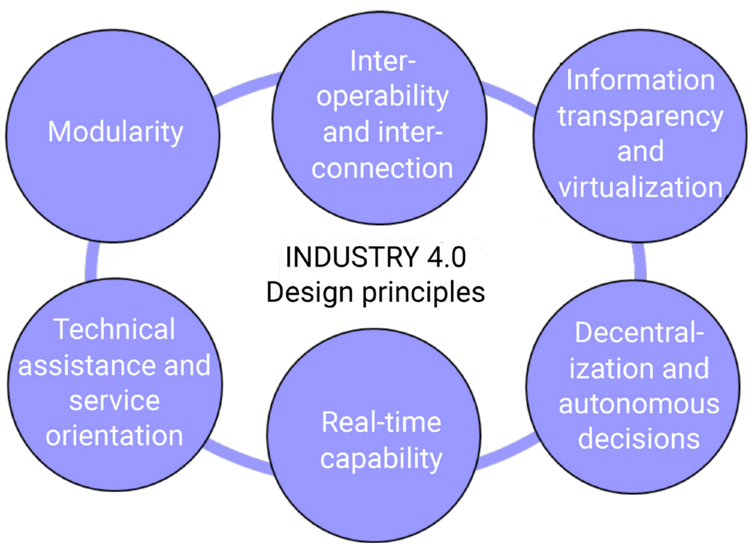
Sensors and actuators are placed into the Field level. They are the interface of every single process. The second level is the Control level. PLC is used to regulate the machine systems. The third level is the Production level. SCADA systems are used to monitor, control, and supervise the product line. MES systems are utilised in the fourth level, which is the Operations level. They are responsible for production planning, quality management and OEE (overall equipment efficiency). The fifth and final level is the Enterprise planning level. It controls order management and processing, enterprise planning, business process management (BPM). According to research in the field of material flow, the most important activity, where improvements can be implemented is order picking, where an ample amount of manual work is present which causes significant time and money loss. Order picking accounts for as much as 55 % of the total material flow operating expense. By applying the principles of Industry 4.0 to order-picking methods, the efficiency of picking can be improved. In zone picking, the whole picking area is divided into several smaller areas (zones). Order pickers are assigned to a specific zone, and only pick items within that zone. Orders are moved from one zone to the next after picking in the previous zone is completed. Usually, conveyor systems are used to move orders from one zone to another.

Zone picking is based on the idea that products are allocated into proper zones to equalise workload among pickers so that they have about the same workload. If the workload is not balanced, some pickers may be busy with too much work while others remain idle without any work to do. Unbalanced workload results in long picking time and less throughput (Živanić et al. 2014, 2019). By introducing autonomous decision making into WMS, the management of orders can be adapted more to the demands. The goal of Industry 4.0 is to make the fifth level independent from human interaction (Industry 4.0: the fourth industrial…) and thus to lower expenses.

Design principles of Industry 4.0

There are six main principles of Industry 4.0, *Fig. 4.* These are interoperability and interconnection, information transparency, e.g. virtualisation, decentralisation and autonomous decisions, real-time capability, technical assistance, and service orientation and finally, modularity.

Figure 4: *Six main principles of Industry 4.0*



System connectivity is based on IoT, and it is essential to establish horizontal and vertical integration. By establishing the connection between tools and superior systems, cognitive system management can be implemented, i. e. the possibility to learn based on received information is provided to machines.

The transparency of information does not only mean that all information is available in the cloud, but it also means that all objects, processes, and systems are transformed into virtual objects which enables simulation and optimisation of all processes.

Decentralisation and autonomy imply lowering cognitive management on the level of particular objects. It means placing AI in every single tool and providing independence during the decision making based on information available in the cloud.

Operation in real-time implies the possibility to make changes in production every moment. By connecting systems and giving them decision-making autonomy, they become capable of reacting instantly when a problem occurs. It is essential that system components can be swiftly changed to provide autonomous and predictive maintenance.

Technical support represents the connection between the product and the production system when the product is used. All the information an intelligent product can collect is returned to the production system. This allows guidance to product users in the case of a product malfunction. Furthermore, it enables production systems to analyse manifested errors and, based on them, improve future products.

Modularity is the essence of production by order. It provides the possibility to change certain parts of a product during production following the desires of the customer.

The smart factory

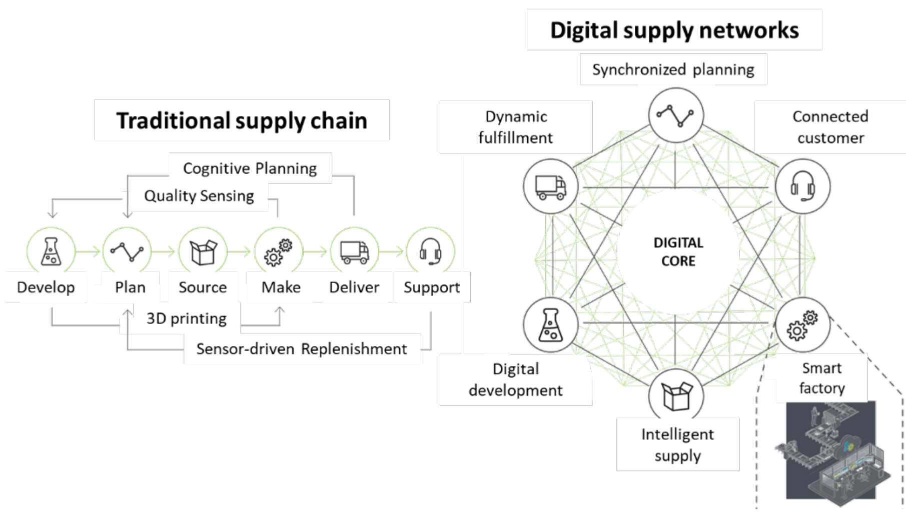
The smart factory represents the next step in the evolution of automation. It represents a fully connected and flexible system which processes a continuous data flow to improve itself and be more adaptive to new demands. Application of the elements mentioned in the previous paragraphs allows for a transformation from linear, sequential, supply chain operations to interconnected, open supply chain operations, i. e. to a digital supply network which integrates information from many different sources and locations, processes it in real-time and controls the physical act of production and distribution (Harrison–Vera–Ahmad 2016).

With the integration of all the data, a more efficient and agile system can be achieved. Also, by less production downtime and better possibility to predict and adapt to production changes can be realised. This provides a better position for the factory on the market.

The term automation refers to one discrete task or process, for example, the opening of a valve or starting a pump depending on predefined rules. By introducing AI and sophisticated cyber-physical systems which can integrate physical production processes with the trends on the market, automation gets a new meaning, i. e. independent decision making that used to be the prerogative of humans only.

Based on the new automation definition, the smart factory represents a flexible system which has the possibility of self-optimisation based on the received real-time data. It is also capable of autonomously running the whole production process. The smart factory changes with the received requests – changes of the customer's desires, a breakthrough on new markets, development of new products or services and all of that because of IT development. According to an estimate of the Bank of America, the adoption of smart factories powered by AI could increase productivity by 30%, while lowering the cost of labour by 18–33% by 2025 (Gisler 2019).

Figure 5: *The transition from traditional supply chain to digital supply network*



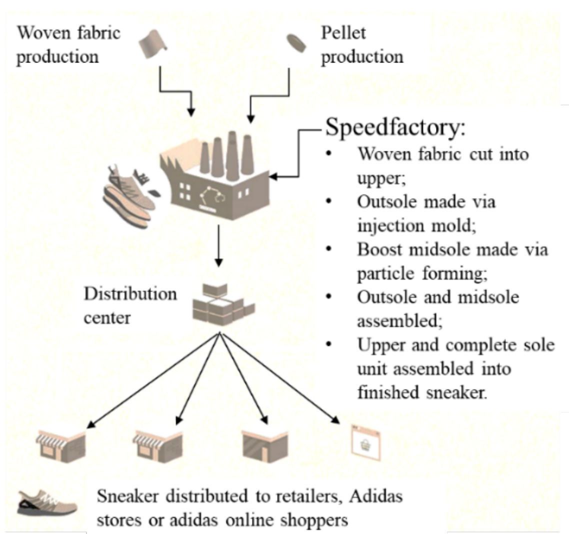
The smart factory can be described through five main characteristics:

- Connectivity – the interconnection of systems is one of the most important characteristics. Smart sensors are used which continuously collect data from the production lines and, with the information which comes from the market, enables a view of upstream and downstream supply chain processes which provides greater supply network efficiency.

- Optimisation – optimisation of a system represents a balanced production flow and extremely high system efficiency. Furthermore, energy management contributes highly to cost cuts.
- Transparency – enables a better overview of the production processes based on the available data in the cloud.
- Proactivity – allows production participants to act before a problem occurs. This feature enables the recognition of production anomalies which can lead to defects or cost increases. Based on proactive maintenance, significant cost savings can be achieved due to the absence of unplanned production downtimes.
- Agility – provides for smart factories the opportunity to adapt to production changes with minimal interventions. Robots change their operating tools on their own by ordering tools from the storage, which lowers downtime and increases profit.

The characteristics listed above provide manufacturers with a better insight into production and allow them to overcome traditional difficulties in a more efficient manner. The example of the Adidas company can show possibilities of the smart factory concept. Adidas tried to solve problems that occur in the manufacture of clothing and footwear - like global fragmentation of production and rapidly shifting demands – by constructing two smart factories (Speedfactories), one in Germany and the other one in the USA.

Figure 6: *Adidas Speedfactory scheme*



Traditional factories have problems with keeping up with ever-shifting fashions. Because Adidas placed his smart factories near the epicentre of demand, they can adapt better to new trends and provide new products faster to customers. They do not produce a trial series of tens of thousands of pieces of a particular model on the sales of which they determine the profitability of that model. They produce a trial series of few hundreds and assess the profitability of the model based on the sales of that small trial series. This is possible due to the location of the factories and the automation of the complete production process without human interference. Robots can change the way they work and adapt to a new model in short notice. Results show that this type of production brings a 15% revenue growth.

The concept showed that even with the introduction of the smart factory in the EU and USA, the cost could not compare with production costs in Asia. Starting at the end of this year (2019), Adidas will use its Speedfactory technologies to produce athletic footwear at two of its suppliers in Asia. The company expects this to result in better utilisation of existing production capacity and more flexibility in product design. Adidas consumers will benefit as the combination of existing technical possibilities of the suppliers, and new production methods developed in Ansbach and Atlanta will allow for more variations of Speedfactory footwear models in the future. These will continue to be characterised by a particularly short production time, allowing the company to continue to respond quickly to consumer needs. Production at the two Speedfactories in Ansbach, Germany, and Atlanta, USA, however, will be discontinued from April 2020 at the latest. In the future, Adidas will concentrate its resources and capacities even more on modernising its other suppliers and using 3D technology in footwear production (Adidas deploys Speedfactory technolog…).

The impact of smart factories on production processes

Manufacturers can implement the concept of the smart factory in many ways and adapt them to present or future demands. The impact of the smart factory concept will be different for each production process. Various manufacturing processes, which can be upgraded with modern technologies, are shown in *Table 1* (Industry 4.0: the fourth industria…).

Table 1: *Processes within a smart factory*

Process	Sample digitisation opportunities
Manufacturing operations	• Additive manufacturing – producing prototypes or low-volume spare parts. • Advanced planning and scheduling – using real-time production and inventory data to minimise waste and cycle time. • Cognitive bots and autonomous robots – effectively execute routine processes at minimal cost with high accuracy. • Digital twin – digitises an operation and moves beyond automation and integration to predictive analyses.
Warehouse operations	• Augmented reality – assists personnel with pick-and-place tasks. • Autonomous robots – execute warehouse operations.
Inventory tracking	• Sensors – track real-time movements and locations of raw materials, work-in-progress and finished goods. • Optimising inventory on hand and automatically signal for replenishment.
Quality	• In-line quality testing using optical-based analytics; • Real-time equipment monitoring to predict potential quality issues.
Maintenance	• Augmented reality assists in maintenance operations. • Equipment sensors to drive predictive and cognitive maintenance analytics.
Environmental, health and safety	• Sensors to geofence dangerous equipment from operating near personnel. • Sensors on staff to monitor environmental conditions, lack of movement or other potential threats.

Conclusion

In this paper, the basic principles of the fourth industrial revolution were presented. They represent the basis for smart factories. The use of smart factories is a holistic approach which connects events inside the factory with activities outside of it. Thus, to achieve a successful result, all factors of the supply chain have to be observed. It is not enough to introduce high technology and connect it to one system. It is necessary to process data coming from the exterior of the factory continually. Concept of a smart factory is not the final step in the automation evolution. This concept is developing continuously, and because of its dynamic nature, it is applicable to all existing production processes. Investments in smart factories enable manufactures to rise above the competition and make their business more efficient.

References

Adidas deploys Speedfactory technology at Asian suppliers by the end of 2019, retrieved from https://yea.to/9uSU2, accessed on 11. 11. 2019.

Benotsmane, R. – Dudás, L. – Kovács, Gy. (2018). Collaborating robots in Industry 4.0 conception, IOP Conf. Series: Materials Science and Engineering, 448, 012023.

de Candia, G. (2019). Industry 4.0 and its aberrations. DOI: http://dx.doi.org/10.13140/RG.2.2.36086.96323.

Gisler, A. (2019). Predictive maintenance and flawless manufacturing, experience, ERNI Management Services AG, 1/2019, 20–39.

Görmüş, A. (2019). *Future of work with the Industry 4.0, International congress on social sciences* (INCSOS 2019). Proceedings book. Edition: 1, Chapter: 32, Publisher: Sageya Yayincilik.

Gubán, M. – Kovács, Gy. (2017). Industry 4.0 conception. *Acta Technica Corviniensis – Bulletin of Engineering,* X, 111–114.

Harrison, R. – Vera, D. – Ahmad, B. (2016). Engineering the smart factory. *Chinese Journal of Mechanical Engineering,* (**29**)6, 1046–1051.

Industry 4.0: the fourth industrial revolution – a guide to Industrie 4.0. Retrieved from www.i-scoop.eu/industry-4-0, accessed on 10. 10. 2018.

Vrchota, J. – Pech, M. (2019). Readiness of Enterprises in Czech Republic to Implement Industry 4.0: Index of Industry 4.0. Applied Sciences. 9. 5405. DOI: http://dx.doi.org/10.3390/app9245405.

Živanić, D. – Vujić, G. – Kosec, B. – Stoić, A. (2014). Material flow enhancement in production assembly lines under application of zoned order picking systems. *Metalurgija,* 53: 681–684.

Živanić, D. – Zelić, A. – Lalić, B. – Simenunović, N. – Szabő, L. (2019). Improving the order picking efficiency by optimising the orders' sequence. *International Journal of Simulation Modelling,* 18: 125–137. DOI: http://dx.doi.org/10.2507/IJSIMM18(1)469.