Basic Technologies and Models for Implementation of Industry 4.0

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Disruptive Technologies of Industry 4.0: Advanced Robotics and Its Implementation in Production Processes

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Abstract: *The implementation of disruptive technologies of Industry 4.0 is carried out in all segments of society, but we still do not fully understand the breadth and speed of its application. We are currently witnessing major changes in all industries, so that new business methods are emerging, as well as transformation of production systems, new form of consumption, delivery and transport. All this is happening due to the implementation of disruptive technological discoveries that include: the Internet of Things (IoT), advanced robotics, smart sensors, Big Data, analytics, cloud computing, 3D printing, machine learning, virtual and augmented reality (AR), artificial intelligence, and productive maintenance. Advanced robotics is one of the most important technologies in Industry 4.0. The robotic application in the automation of production processes, with the support of information technology, leads us to ''smart automation'', i.e., ''smart factory''. The changes are so profound that, from the perspective of human history, there has never been a time of greater promise or potential danger. New generation robots have many advantages compared to the first-generation industrial robots such as: they work alongside with workers, workers perform their tasks in a safe environment, robots take up less space, robots do not need to be separated by fences, robots are easy to manipulate and cheaper to implement. The paper analyzes the trend of implementation of collaborative and service robots for logistics, which make the automation of production processes more flexible. Robotic technology is the basic technology of Industry 4.0, because without its application, the implementation of Industry 4.0 would not be possible. The trend of application of new generation robots will have an increasing character in the future, because the goals of the fourth industrial revolution cannot be achieved without collaborative robots. In other words, the objective is to achieve a ''smart production process'' or ''smart factory''.*

Keywords: *disruptive technologies, Industry 4.0, robot, flexible automation, production process, smart factory.*

1. Introduction

The implementation of disruptive technologies of Industry 4.0 in production processes enables the creation of connected company that allows production

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processes to discover new ways of increasing productivity and improving overall business performance.In order to ensure this, it is necessary to have a secure connection between different production systems and processes throughout the company. The new way of managing production processes aims to improve performance and better use of data that already exists by using a combination of tools that can be used to improve the system or production process [1-3]. If the disruptive technologies of Industry 4.0 are implemented in the entire company, and by integrating processes and serialdiscrete drives, efficiency and productivity will increase in all segments of the company. When we have access to production data in the production process at any moment in real time, it allows us to monitor and improve the performance of the production process itself, which enables us to implement the basic technologies of Industry 4.0. The term Industry 4.0 is already widely used, and it is related to different production concepts [4-6].The concept of Industry 4.0 is defined by many technologies (over 40 technologies). Some of these are: robotics, automation, Internet of Things (IoT), Big Data, Cloud Computing, 3D printing, smart sensors, Radio Frequency Identification (RFID), Virtual and Augmented Reality (AR), Artificial Intelligence (AI), advanced security systems, Cyber-Physical Systems (CPS), etc., as shown in Figure 1. Cyber-Physical Systems (CPS), Internet of Things (IoT), Artificial Intelligence (AI), Additive Manufacturing, Cloud Computing, and other aforementioned technologies are combined to construct dynamic, real-time optimized and self-organizing networks of values between production processes and companies. All listed components are necessary for the implementation of Industry 4.0. New generations of industrial robots have numerous advantages compared to the first-generation of industrial robots, such as: during the production processindustrial robots do not have to be separated from workers (today they work together with workers), they are light and flexible so they can be easily moved and just as easily and simply reprogrammed to perform new tasks. With these robots, automation becomes easier, more flexible, cheaper, and leads to ''smart automation''. The development of new technologies, new methods and innovations, as well as progress in industrial production resulting from these trends, presents new challenges for the robotics industry. By implementing second-generation robots or collaborative robots, we increase the reliability of the production process, reduce the production time of the finished product, and increase precision and adaptability, which exceeds human capabilities. Until now, automation has been too complex and expensive, because the installation of one industrial robot used to costabout two years' salary of one worker, and the use of a collaborative robot costs about half a year's salary. Continuous implementation of collaborative and service professional robots is necessary to have flexible automation. Robots are used to improve the quality of work, to take over dangerous, dirty and boring jobs that humans are unable to perform due to health problems or due to complexity that require flexibility, precision and reliability that humans do not have [5,6].

2. Disruptive technologies enable constructionof networking production environment

From a technological perspective, Industry 4.0 should be understood as the increased digitization and automation of production processes, that is, the networking of the production environment and the design of the digital value chain from the product to the customer. Some authors call the basic technologies of Industry 4.0 new disruptive technologies, which is inevitable because the world is in the dynamic era, and they change the production processes that are currently implemented in most companies [2, 3]. It is well-known that disruptive technologies are considered those technologies that change rooted (widespread) business processes, and even entire industries, by introducing a completely new business model based on technology. Many questions arise in the process. How to quickly profit from new disruptive technologies? How to create opportunities and at the same time maintain a good image and reputation? How to get your own organization and people on your side? Company owners are known to like controlled progress and improvements. The question is whether it is possible to achieve it in such a fast-changing disruptive reality, which becomes a burning issue for 70% of company owners.How to cooperate with other companies on innovation projects? How do we know if we can trust them? The dilemma of management consists of the fact that we are aware that we have to cooperate with others, but we must not risk losing our investments due to partners who could deceive us.

It must be noted here that innovation in disruptive technologies means the process of developing new products or services in order to replace existing technologies and achieve a competitive advantage. Namely, a disruptive product or service is aimed at a market that they could not satisfy before (new market disruption) or represents a simpler, cheaper or more economical alternative to existing products (cheaper disruption) [7].

We can see that many markets in the world have already been shaken up by new companies that offer surprising new products and services, or have innovative business models or an aggressive market strategy. Some of these well-known names are Tesla, Uber, Airbnb, SnappCarr, Nextdoor, Waze, Spotify, Picnic, HelloFresh, Zaalando, Booking.com, Virgin and Amazon. All of the above are young companies that became successful because they implemented disruptive Industry 4.0 technologies in their sector. Basic disruptive technologies in production processes are shown in Figure 1 [7].

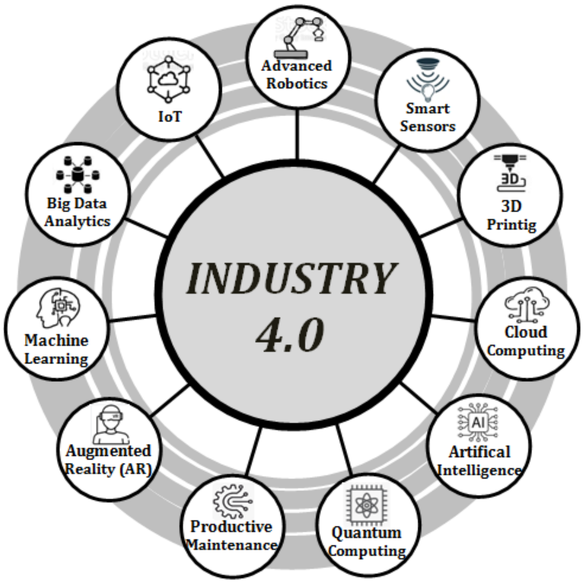


Figure 1. Basic disruptive technologies in production processes

The very concept of Industry 4.0 defines over forty technologies used by companies to meet the demands of customers, which are increasing day by day. In production processes, companies mostly use the disruptive technologies shown in Figure 1, such as: the Internet of Things (IoT), advanced robotics, smart sensors, Big Data, analytics, cloud computing, 3D printing, machine learning, Virtual and Augmented Reality (AR), Artificial Intelligence, and productive maintenance, which represent a completely new approach to modern manufacturing and business that is mostly focused on the consumer. Using the aforementioned technologies, the companies try to meet the demands of customers and close the gaps that arise in skills, but also take advantage of human expertise and investment in the implementation of the mentioned technologies in order to increase their level of productivity in production processes. The above-mentioned disruptive technologies enable secure communication within production processes, as well as simplified communication between all participants in the supply chain, regardless of where it is located. These technologies enable the monitoring of production processes and, in critical situations, making the right decision in order to ensure continuous production. We will list the basic and specific characteristics of each of the mentioned disruptive technologies of Industry 4.0 [1-3]:

- ***The Internet of Things (IoT)*** represents a system of interconnected computer devices, mechanical and digital machines, objects, animals or people with unique identifiers and the ability to transfer data via a network without human intervention or human-computer interaction. We can conclude that the desire is to connect all our devices together, that will communicate with each other and act on the basis of the information they receive from each other. In the production process, this means establishing standards based on models for connecting devices, machines and automation to a single digital platform or infrastructure, which we call the Industrial Internet of Things (IIoT). The concept of IIoT itself is similar to the concept of IoT, but it is more focused so that a network of smart sensors collects a large amount of critical production data, and forwards it to the data analysis software in the cloud. After the analysis and processing of the obtained data, information is returned about the insight into the quality and efficiency of the production operations that we monitored in the production process. With the implementation of Industry 4.0 in the company, IoT devices are deployed to monitor and control electronic, mechanical and electrical systems in production processes, in the assembly process and fully automated production processes. By implementing this disruptive technology, companies use it to manage and optimize the supply chain, gain strategic awareness of data visibility throughout the chain from procurement to delivery, and have complete control, so they can adapt to the changing market. In this way they are able to deliver services and products to the customer more efficiently, more profitable and at a higher quality rate than competitors.

- ***Big Data - analytics*** is a disruptive technology and architecture that can use the values of a large amount of different data and their processing and analysis in real time, where changes in the speed of accumulation, volume of data and types of data are included. To date, a wide range of techniques have been developed and adapted such as: A/B testing, Association rule learning, Classification, Cluster analysis, Crowdsourcing, Data fusion and data integration, Data mining, Ensemble learning, Genetic algorithms, Machine learning, Natural language processing (NLP), Neural networks, Network analysis, Optimization, Pattern recognition, Predictive modeling, Sentiment analysis, Regression, Signal processing, Spatial analysis, Supervised learning, Statistics, Time series analysis, Visualization, etc., which draw on disciplines such as statistics and computer science (especially machine learning) to be used to analyze data sets. Likewise, there is an increasing number of technologies that are used to aggregate, manipulate, manage, and analyze big data, some of which are: Business intelligence (BI), Cassandra, Non-relational database, Relational database, Semi-structured data, Stream processing, Structured data, Unstructured data, Visualization, etc. All the mentioned techniques and technologies draw on developed methods and algorithms from several fields, including statistics, computing, applied mathematics and economics.The above list of techniques and technologies is not exhaustive because more technologies that support big data techniques are increasingly being developed. By using big data analytics, companies discover valuable correlations, patterns, and trends on the basis of which they make better decisions, whereas their application enable manufacturers to experience efficiency in production, have predictive optimization maintenance, as well as automated management of production processes. By implementing this Industry 4.0 technology in production processes, the company has the ability to discover hidden variables that cause bottlenecks in production processes, and is crucial for real-time performance.Likewise, by using big data analytics, it is possible to optimize the supply chain, predict errors, product development, as well as the smart design of the company.

- ***Smart sensors*** can be defined as a device that measures a physical quantity, gives an output signal that depends on the amount of the measured quantity, converts it into a signal suitable for further processing, uses computer resources that are built into the sensor to perform a predefined and programmed function on a certain type of data which it collects, and then forwards that data over a network connection. The implementation of smart sensors, which are synonymous with Industry 4.0, monitors various production processes, collects data, makes measurements and transfers data to cloud computing platforms where the obtained information is analyzed for making decisions that are essential for improving the production process. The development and implementation of smart sensors takes place on a daily basis.The most common smart sensors used in production processes are level sensors, temperature sensors, pressure sensors, infrared sensors, proximity sensors, etc. It is expected that the development and research in sensor technology will lead to sensors that are biodegradable. This type of research requires more than 10 years.
- ***3D Printing*** is the production of elements and objects by computer-controlled robots that deposit layers of a specific material and thus form parts and objects from computer-aided design (CAD). 3D printing is used in almost all industries, especially in the automotive and aerospace industries for product redesign, and achieves lower material consumption and more complex geometry in order to increase efficiency. By implementing this Industry 4.0 technology using 3D software, which is known as generative design, it is possible to produce parts that have complex geometry, and cannot be produced by traditional production methods. Such 3D models, which are produced by generative

design software, use elements of artificial intelligence (AI). This disruptive technology of Industry 4.0 is in the research phase, and the very stability of the production of parts with this technology will begin to change, increase and enable digital transformation and product innovation. It will enable easier exchange of knowledge in the entire supply chain, as well as collaborative production in production processes.

- ***Cloud Computing*** is information technology (hardware and software) that describes the provision of IT infrastructure such as data storage space. In other words, it describes access to IT infrastructure that is available via a computer network without having to be installed on computer. The best example is companies that provide e-mail service, which store messages using cloud computing. This technology allows companies to focus on their core business, rather than spending their resources on computer infrastructure and its maintenance. This disruptive technology enables companies to simplify certain operational and management processes, centralize data storage that users can easily access, and provide real-time information exchange.Some of the advantages of this technology are reduction of costs, reduction of energy consumption, flexibility, efficiency, stability, exchange of company data independent of location, etc. Like any technology, this technology also has its disadvantages, some of which are data protectionand dependence on the IT network. The types of services in Cloud Computing are Software as a service SaaS, Platform as a Service PaaS, and Infrastructure as a service IaaS.
- ***Machine learning*** is a technology that enables computers, or computer programs, to have this ability. One of the most important abilities of human intelligence is learning, both from one's own and others' experiences, which results in the recognition of patterns based on experiences. According to Tom Mitchell's definition from 1997, machine learning implies a computer program M (Machine) that learns from experience E (Experience) for a task T (Task) where P (Performance) denotes success, if its success P in the execution of the task T increases with experience E. The implementation of machine learning in the production process improves the quality of production by detecting errors before they appear. Manufacturing companies using smart factories can perform machine learning-based automation testing to improve engineering processes and ensure fully optimized quality control. By implementing the technology, machine learning can recognize patterns and apply them to new situations in automated production processes and other areas of Industry 4.0 such as autonomous service robots in production assembly lines.

- ***Digital twin*** is a virtual copy (digital model, layout, mirror image, sample, pattern) of an imagined or real physical product, system or process in the real world (system, product, process that is simulated, i.e., real), which can serve different purposes as a digital equivalent. A digital twin is nothing more than a computer program (software) that uses data from the real world to create simulations that can predict the way a product or process will behave. These programs most often combine and integrate the Internet of Things, Artificial Intelligence and Big Data analytics to improve results. In other words, a digital twin is a digital representation of a physical object, process, service or environment that behaves and looks like its counterpart in the real world.
- ***Artificial intelligence*** is the ability of a device to imitate human activities such as reasoning, learning, planning and creativity. Artificial intelligence enables technical systems to perceive the environment, take into account what they see and solve problems to achieve a goal. The computer receives data (which has already been prepared or collected using its own smart sensors, e.g., a camera), processes it and provides answers. Artificial intelligence systems can adjust their behavior to a certain extent by analyzing previous situations and working independently. Some artificial intelligence technologies have been around for more than 50 years, but advances in computing power, the availability of vast amounts of data, and new algorithms have led to major breakthroughs in the field of artificial intelligence in the recent years. As it is predicted, artificial intelligence will bring huge changes in the future, although it is already present in our daily lives. Artificial intelligence is widely used to provide personalized recommendations, for example based on previous searches and purchases or other forms of online behavior. Artificial intelligence is extremely important in commerce, product optimization, inventory planning, logistics, etc. In addition, it is used for machine translation, search, cars, cyber security, fighting disinformation, during the Covid-10 pandemic, etc.
- ***Augmented Reality (AR)*** is one of the disruptive technologies. It works on the principle of overlaying digital objects and information on the screen of a phone, tablet or headset by recording the physical environment in real time. Augmented Reality (AR) is implemented in an industrial environment on production assembly lines. It is used to train employees in the production process for various processes of maintenance of the production process, as well as repairs on various products of industrial production. Implementation of this Industry 4.0 technology transforms the life cycle of product design. Its implementation in production processes in industry replaces traditional

paper manuals with digital instructions. It is effective when it comes to industrial training in assembly, maintenance and repair. Augmented Reality (AR) makes the verification process much faster than traditional methods. Its implementation in quality control enables production processes to verify the placement of the component in the assembly by confirming the work instructions in advance. Likewise, its implementation in logistics increases operational efficiency in the areas of storage, routing and transportation of goods. AR glasses can be worn by warehouse employees to identify the shortest path to locate and select items needed for shipment.

- ***Predictive Maintenance*** – implementation of this technology assesses the condition of industrial equipment by performing periodic or continuous (online) monitoring of the machines and devices. A series of smart sensors that send data to a centralized or decentralized network of hardware and software are implemented in the machines and devices that work in the production process. A predictive maintenance system is designed to analyze data patterns from interconnected sensor data and predict when maintenance should be scheduled. It is generally performed while the equipment is operating normally to minimize disruption to day-to-day operations. The implementation of this Industry 4.0 technology aims to prevent asset failure with far greater precision and far less downtime, and it is useful for manufacturers as it helps extend the life of equipment by early detection of mechanical irregularities in devices and machines operating in the production process. Companies that implement this technology have advantages because they get a reduction in maintenance costs, an extension of the life cycle of old equipment and a reduction in downtime to improve production. Its implementation in production processes leads to valuable data important for the improvement of production.
- ***Advanced robotics*** – the development of advanced technologies has led to collaborative robots, i.e., the second-generation industrial robots and service robots used in industry. We can also call it advanced robotics, which we define as a combination of sophisticated programming and powerful hardware that uses smart sensor technology (including ultrasonic, touch and light sensors) to interact with the real world around you. The new generation of robots is impacting manufacturing, sinceproduction processes grow in complexity and scope thanks to digitization and the application of advanced computing technologies such as artificial intelligence (AI) to multiple areas of product design, manufacturing, supply chain and retail. The implementation of second-generation robots, or advanced robotics, is increasingly being applied to help simplify initiatives, as the new, more complex operating

environment demands an ever-increasing amount of automation. The implementation of Industry 4.0 uses advanced robotics as a base technology to increase productivity, to perform and take over tasks that are done manually, to perform tasks faster and to reduce the time of product creation. In addition, the use of second-generation robots or collaborative robots offers another advantage over conventional robots in that they are easier to set up and configure on the assembly line from the start of their implementation. Advanced robots can also take advantage of simulation software to learn how to perform a series of tasks. Manufacturers are improving quality, reliability and precision on the assembly line by closing the skills gap with technology. Collaborative robots or second-generation robots are able to do this because they have the ability to adapt themselves when the procedures and the process itself change in the production process, while industrial robots did not have this ability to adapt because they had to be separated by fences so as not to injure the workers. Finally, we can conclude that advanced robotics uses smart sensors to meet the requirements of a complex production environment for automation.

By implementing the mentioned and described basic disruptive technologies of Industry 4.0 in production processes, they become digital, and the nature of production processes is transformed with the aim of creating a connected supply chain with optimized production. With the implementation of disruptive technology of Industry 4.0, companies have a unique opportunity to efficiently respond to the increasing demands of customers' needs, which are growing on a daily basis [7-9]. Companies must discover the true values of Industry 4.0 and thus improve the efficiency of the process, enable faster and simpler decision-making, as well as achieve operational growth in evaluating important criteria for the performance of a product or service. Every sector will have to face disruption and the implementation of disruptive technologies. The best example is the banking sector, where over 85 % of all payments are made online. We have countries that are the opposite example, so in China, about 85 % of online bank payments take place through non-banking companies, namely Alibaba and Samsung. In the future, an increase in the implementation of disruptive technologies is expected in all segments of society worldwide, and many disruptive innovations are expected to be implemented in health care, so that certain companies such as Apple, IBM (Watson), Philip, GEMedtronic, Johnson & Johnson, have already launched platforms for medical applications. The disruptive technologies of Industry 4.0 are the latest paradigm shift, as the term Industry 4.0 is used as a synonym for the latest major disruption in the way we use technologies (so far) in production processes [10-12]. The German government's strategy aimed to offer a strong adaptation in connection with mass production using the aforementioned technologies. However, the implementation of disruptive technologies of Industry 4.0 nowadays refers to new ways in which the offered technologies communicate with society and people. Innovations in disruptive technologies of Industry 4.0 such as: advanced robotics, Internet of Things (IoT), artificial intelligence, additive technologies, biotechnology, nanotechnology, autonomous vehicles, etc. take place according to an exponential function in relation to all other technologies, where innovations take place according to a linear function that has a slight increase[13,14]. Unlike the three previous industrial revolutions, this fourth industrial revolution differs because Industry 4.0 relies on advances in the sharing and use of large amounts of information, and it has the potential [15]:

- To connect everything and put it on the web,
- To make the business as efficient as possible,
- To help protect and regenerate the natural environment by introducing new management technologies.

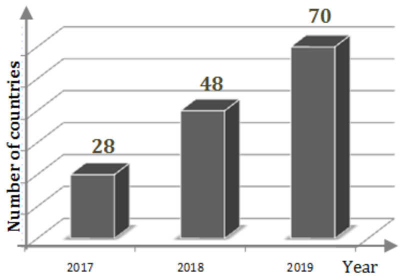
There is a trend towards increased data exchange and automation in production technologies, as well as the development of cyber-physical systems that interact with each other and humans in real time. The implementation of Industry 4.0, i.e., disruptive technologies, benefits companies, which is reflected in the optimization of complex production processes, the transformation of production processes, as well as the establishment of monitoring of production processes and other activities [16 -18]. Each company adapts to the implementation of Industry 4.0 in different ways table 1 [18]. Every technological development causechange on all levels, from the day-to-day activities of individuals to the dramatic competition between global superpowers. It is well-known that the implementation of new technologies regularly changes the course of life, communities and civilizations. Similarly, the implementation of disruptive technologies of Industry 4.0 brings changes that we expect to be positive at all levels. Nevertheless, their implementation can also bring disruptions that can have negative connotations, because its effects depend on the perspective. Let’s give one example of a positive change. The first positive example is the implementation of disruptive technologies during the COVID-19 virus pandemic. A pandemic may be a natural disruption in the sense that it is a biological phenomenon. However, the pandemic has enabled the active implementation of disruptive Industry 4.0 technologies that enabled human activities such as the search for treatments and vaccines, the development of contact tracing applications, and the widespread shift to work from homes and socializing at a distance through Internet communications, as well as global trade.

With the implementation of the mentioned disruptive technologies, the pandemic of the COVID-19 virus was stopped (they were like an antidote to the disorder), normality was established in society so that society will become even more dependent on the mentioned technologies.

Table 1. Visual improvement of a certain number of disruptive technologies of Industry 4.0[22]

Disruptive technology	A visual improvement of disruptive technology	Products, groups and resources affected by disruptive technologies	Impact of disruptive technologies on economic values
MOBILE INTERNET	Sales of tablets and phones have increased six times since the first iPhone (since 2007). In 1975, the price of the fastest computer is like the price of an iPhone 4, which has the same performance (MFLOPS).	4.3 billion people are connected via mobile internet. Almost 40% of the global workforce is in a agreement and interaction (about one billion).	70% of global employment costs. GDP related to the Internet (about $25 trillion).
THE INTERNET OF THINGS	In the last 5 years we have 300% increase in connected machines (M2M). In the last 5 years, prices have dropped by about 80-90% MEMS (micro-electronic systems) and sensors	It is assumed that 1 trillion devices will be connected to the Internet (in manufacturing, healthcare, mining, etc.) Machine-to-machine (M2M) connectivity is predicted to be around 100 million in the security, transportation, healthcare, etc. sectors.	Operating costs for manufacturing, healthcare and mining around $36 trillion.
AUTOMATION OF KNOWLEDGE WORK	We have a 100x increase in computing power from IBM's Deep Blue to Watson. In the last 5 years, over 400 million increase in the number of users of digital assistants such as Siri and Google Now.	About 9% of the global workforce are knowledge workers, over 230 million. We have around 1.1 billion smartphone users, who have the potential to use digital assistance apps.	About 27% of the global employment costs for professional workers are necessary over 9 trillion dollars.
CLOUD COMPUTING	It takes 18 months to double server performance per dollar. The monthly cost of owning a server is 3 times higher than renting a cloud.	In the cloud, there are over 2 billion global users of email services such as Hotmail, Gmail and Yahoo. Over 80% of North American tourism companies have cloud applications.	Internet-related GDP exceeds $1.7 trillion. IT spending by companies exceeds 3 trillion dollars.
3D PRINTING	The price of a home 3D printer is 90% lower than 4 years ago. Revenues from additive technologies have increased four times in the last 10 years.	About 12% of the global workforce, over 320 million are production workers. Over 8 billion toys are produced annually in the world.	Over 11 trillion dollars of global GDP. Global revenue from sold toys over 85 million dollars.
ADVANCE ROBOTICS	The price of collaborative robots is lower by about 70-80% compared to industrial robots of the first generation, In the last 10 years, robot sales have increased by about 310%	About 14% of the global workforce works with robots over 340 million. Annually, they increase by over 250 million operations performed by robots.	The cost of employing manufacturing workers is about $6 trillion. Costs for major operations are around 2-3 trillion dollars.

Another negative example of the implementation of disruptive technologies of Industry 4.0 is stated in a study by the Oxford Internet Institute (OII) from 2019, which reveals the increase in the manipulation of social media by governments and political parties around the world, as shown in Figure 2.



Data source: Oxford Internet Institute [15]

Figure 2. Block diagram of the increase in organized manipulation of social media in the period 2017-2019

A study by the Oxford Internet Institute (OII) shows evidence that the following countries: Russia, Saudi Arabia, Iran, Pakistan, Venezuela and China have engaged in information operations to influence foreign audiences through Facebook and Twitter in 2019 [15]. Many countries use the mentioned technologies to influence the domestic audience, as shown in Figure 2. In 2017, 28 countries used technologies to influence the domestic audience, in 2018 the number of countries increased to 48, and in 2019 70 countries used the aforementioned technologies to manipulate the domestic audience. This is an example of how governments and political parties use disruptive technologies in the country to control information, suppress basic human rights, discredit political opponents and suppress disagreement.

Now that we see that the implementation of disruptive technologies is causing technological disruption, and with regard to technological development and changes in business models, it is necessary to establish adaptive regulation [15,19,22]. In order to establish adaptive regulation for this purpose, a ‘’smart regulation’’ approach will help policy makers to formulate more flexible, imaginative and innovative (especially in the field of new technologies such as AI and Fintech) forms of policy instruments [23]. As there is no agreed definition of smart regulation in the world, a number of key principles for smart regulation can be identified, as shown in Figure 3.

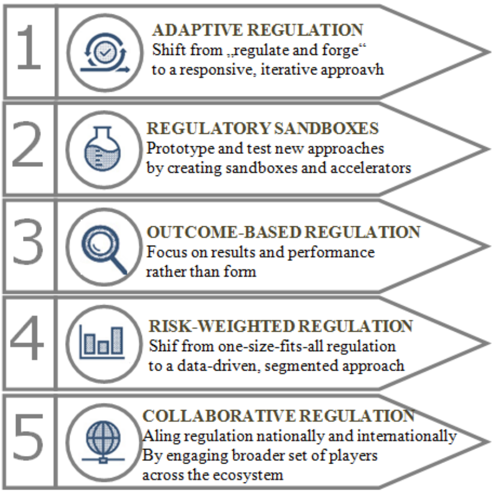


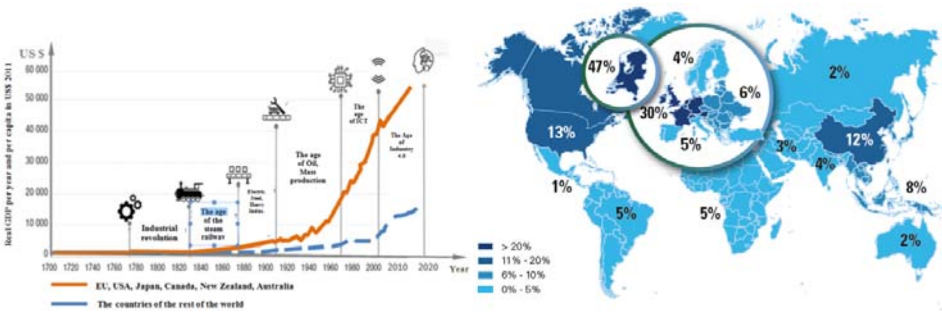
Figure 3. Block diagram of key principles of smart regulation
Data source: Deloitte [53]

The principles of smart regulation consist of five steps:

- *adaptive regulation* – where one would switch to an appropriate iterative approach,
- *regulatory sandbox (blockchain)* – prototype and testing of new approaches to sandbox creation,
- *outcome-based regulation* – focus on results and performance, not form,
- *risky regulation* – the recommendation is to abandon the regulation of one size, and go in the direction of a segmented approach based on data,
- *joint cooperation* - arrange regulations at the national and international level, by engaging broad groups throughout the ecosystem.

Smart regulation primarily refers to a response aimed at cyclical regulation, not long-term rules that set fixed legal standards for decades. Smart regulation is also about responding to problems of coordination and knowledge by being more interactive and involving multiple stakeholders, including interest groups.
The goal of the implementation of disruptive technologies of Industry 4.0 is smart production in which we have operational information in real time, reduce risk in the supply chain, reduce inventories and achieve efficient production, as well as increase of GDP, as shown in Figure 3. [7,22,23]. It is necessary to build a set of skills both inside and outside. A graphic representation of the implementation of disruptive Industry 4.0 and their impact on technological changes and inconsistencies throughout the centuries, and the increase in GDP, is shown in Figure 4.a). By analyzing Figure 4.a) we can conclude that in the last fifty years the biggest jump in the increase in living standards is thanks to investment in research, development and implementation of advanced

technologies. Many leading companies in the world are investing and implementing advanced technologies that are the key technologies of Industry 4.0. In many companies, significant progress has been recorded thanks to artificial intelligence, machine learning, the increase in available data that grows exponentially, as well as the improvement of statistical methods, i.e., advanced data analytics in digitalization and automation in production processes.



a) Increase in GDP b) Market of future expected growth

Figure 4. Impact of disruptive technologies in the world on GDP growth and the market of future expected growth of foreign markets in 2016 and beyond [7,23]

Another example is the market analysis that was conducted [23]in the Netherlands in 2016 and shown in Figure 4.b), which predicts the possibility of increasing the economy in the future. All companies see opportunities and chances to increase the economy not only in the Netherlands but also on the foreign market. Half of the companies (of those tested) predict that foreign markets will become more important in the future than the Dutch market, when considering the disruptive technologies of Industry 4.0. The estimated percentages of foreign markets for 2016 and beyond are shown in Figure 4.b), where we can see which countries and continents will have future expected growth in percentages. In order to survive and stay present on the global market, it is necessary for companies to optimize equipment, which must be reliable and safe, minimize equipment downtime, and improve problem solving. The implementation of Industry 4.0 technologies simplifies development, reduces costs and enables advanced and safer systems while meeting real-time requirements of security, energy efficiency, safety and reliability. Most importantly, it helps drive global competitiveness.

3. Advanced robotics: review of the second-generation industrial robots – collaborative robots

It is well-known that first-generation industrial robots have been implemented in all industrial branches in the world. They make about 94 % of the total number of robots used. Their implementation at that time (1960s) was welcomed for the automation of production processes in all industries. However, it was a rigid automation, since the workspace of the robot needed to be separated by a fence from the workspace of workers in the same production process, so that workers could be protected. The development of science leads to the development of advanced disruptive technologies such as: sensor technology, new materials, information communication technologies, advanced robotics and others, which led to the development of the second-generation industrial robots or collaborative robots. By implementing collaborative robots and other Industry 4.0 technologies, rigid automation of production processes is transformed into flexible automation. The second-generation industrial robots compared to the first-generation industrial robots have a large number of advantages. One of the most important advantages is that the robots do not need to be fenced off and can work alongside the workers because every second-generation industrial robot has a double protection system when it comes to workers. In order to be relevant on the global market, every company must continuously monitor the development and application of new technologies, and implement them in its production processes[20-21]. The development of digital technology is credited with the large-scale implementation of the basic technologies of Industry 4.0, which has led to a rapid flow of information so that the customer expands his requirements and seeks products that are more and more complex to manufacture. Likewise, the development of new technologies leads to market demand for different products with different designs (for example, the automotive industry). Companies must be ready for these challenges and have such production processes that they can very quickly adapt for the production of products of a different design or a different product, which is difficult to implement because it takes a long time.

Leading companies, especially in the automotive industry worldwide, are actively working on the implementation of disruptive Industry 4.0 technologies in the production processes of the industry, thus using new information and communication technologies (ICT) in order to produce more efficiently, productively and flexibly [27-29]. In order for leading companies in Germany to maintain their leading position in the production and development of technologies and standards, thy must implement new disruptive technologies so that they are the first in the export of ready-made solutions. The governments of the leading technological countries have adopted their strategies for the digitization of production processes, i.e., the strategies for the implementation of

Industry 4.0, where they want to create high quality products, to make a renaissance of production, and connect the industry to the Internet. In other words, leading companies want to modernize their production processes, and make them intelligent through the application of advanced technologies. The first step towards an intelligent production process is the implementation of industrial robots of the second generation, i.e., collaborative robots. The world is currently working on the research and development of second-generation industrial robots, i.e., collaborative robots with the aim of their continuous implementation in production processes, so that workers can safely work together with robots. This will help people in carrying out their daily tasks without any risk. Likewise, it is important to automate processes that could not be automated with the first-generation industrial robots.

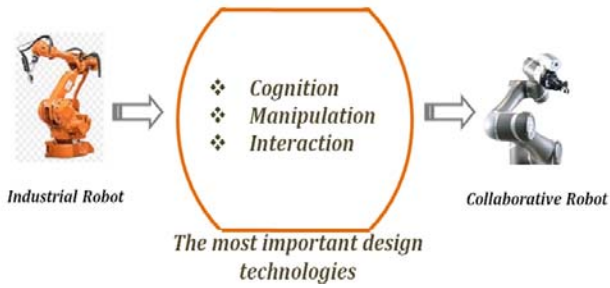


Figure 5. The second-generation industrial robots – collaborative robots are equipped with three new technical solutions compared to the first-generation industrial robots [30,31]

Companies involved in the development and production of advanced robots are facing many challenges. These challenges in the development of robotic technology, from the first-generation industrial robots to the second-generation industrial robots – collaborative robots, lie in three directions, that is, three technical areas, as shown in Figure 5.

The first challenge is knowledge that gives the robot the ability to perceive, understand, plan and move in the real world. This technical solution improves the robot's cognitive abilities so that the robot can work independently in various complex environments. The second challenge is the manipulation that gives the robot precise control and readiness. An advanced robot manipulates objects in its environment. In this way, we have a significant improvement when controlling the robot, which allows the robot to take on a greater diversity in performing tasks in different production processes. The third challenge is interaction, which represents one of the most important areas, because it gives robots the opportunity to learn and cooperate with people. Furthermore, it implies the improvement of robot-human interaction, both for verbal and non-verbal communication. The robot has the ability to observe and copy human behavior and learn from experience [31-33]. An absolute requirement for robots to work with people in an unorganized environment is safety, which is in the first place. We must note that collaborative robots are not intended to completely replace workers, but to work together with them. During the work, it is the worker that performs work in different fields, very complex operations and analytical tasks, while the second-generation – collaborative robot performs simple, monotonous repetitive operations, can handle dangerous materials, as well as lift heavy objects. Let's list some advantages that a worker has compared to an industrial robot:

- Worker has flexibility,
- Worker is ready and able to make decisions independently,
- Worker can independently solve problems, even the ones that arise in the work itself.

Industrial robots also have certain advantages compared to workers, some of which are:

- Collaborative industrial robot has endurance that is greater than that of worker,
- Collaborative industrial robot has power,
- Collaborative industrial robot has greater precision than a worker,
- Collaborative industrial robot has sensitivity.

The second-generation industrial robots – collaborative robots have the following advantages in relation to workers and the first-generation industrial robots: handling of dangerous substances (dangerous chemicals that have an impact on the health of workers, objects of high temperature, etc.), lifting loads greater than 20 kilograms, and reducing injuries at work. With the implementation of collaborative robots and service robots for logistics (such as automated guided vehicles AGV/AMR), an increasing number of production processes and logistics systems are fully automated [40]. With their improved capabilities, collaborative robots can be the key to new services and innovative production processes.

When implementing collaborative robots, safety priorities must be taken into account, because they work side by side with workers in the production process. Companies engaged in the construction and production of industrial robots are faced with a wide set of safety requirements, guidelines and standards. Here we must note that, in order to ensure reliable performance and safety, manufacturers, suppliers, integrators and operators must validate and assess the compliance of a collaborative robot according to a number of different standards, as well as take into account application-specific requirements. Companies that produce robots have found that the increase in cooperation between humans and collaborative robots expands the possibility of automation, which means an increase in the implementation of robots in all production processes. This is one of the reasons that companies develop their own solutions to meet the safety requirements of the work of collaborative robots and humans together. This paper will provide explanationof a couple of solutions developed by certain companies. The second-generation industrial robot-collaborative robot has great sensitivity because it has built-in advanced sensors such as integral force and torque sensors, as well as visual sensors that provide a safe working space and protective zones, safe collision detection, safe tool detection, safe force monitoring, etc. [26-28]. The safe protection zone can be ensured by monitoring the speed of the robot's work depending on the distance of the worker from the robot itself, as shown in Figure 6.

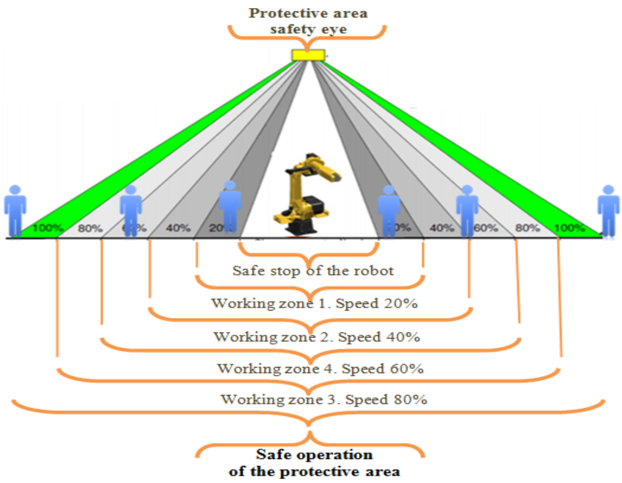


Figure 6. Ensuring the safety zone of the collaborative robot by monitoring the speed of the robotdepending on the distance from the workers [28]

The collaborative robot can easily be programmed to perform different tasks, thus giving it greater flexibility. The automatic work cycle of the collaborative robot is flexible enough to easily adapt the characteristics of the robot to the individual execution of tasks. The safety of workers during the work with collaborative robots is ensured in the work area defined by the standards ISO 10218 and ISO 13849, where functional safety must be ensured, i.e., there must be a safe protection zone. The collaborative robot is designed with sensors for direct work by interacting with workers within a common defined workspace. Such a double check safety system (DSC – dual check safety) was developed by the company ''FANUC'', as shown in Figure 7.

The DSC system is based on the laser sensor. Itmonitors additional safety, and controls the robot accordingly. When the worker is not in the specified three zones, the robot performs its work tasks at full designed speed. When the worker enters the speed reduction zone, the sensor gives information to the PLC, which gives the command to reduce the speed of operations. If the worker continues to move into the protection zone, the speed of operations continues to be reduced, and the ''Contact stop'' is activated. If the worker enters the working area, the robot switches to collaborative work mode, reduces teh working speed and ''Contact stop'' is still on.

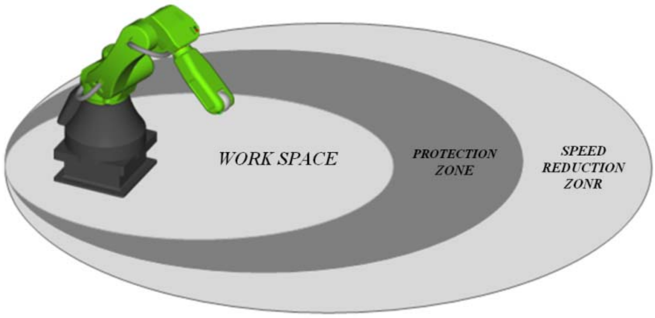


Figure 7. Securing the safety zone of the collaborative robot, DSC – Double Safety System of the company ''FANUC'' [27-29]

When the worker touches the robot, receiver or workpiece, the robot stops performing tasks (stops working). When the worker moves away, the robot continues working at a speed that depends on the zone in which the worker is located. Collaborative robots are coated with a soft coating that is sensitive so that when the contact exceeds a force of 150 N, the robot stops. Since these are sensitive sensors, the contact force can be changed in software (so that it can be lower or higher than 150N). An example of robot-worker contact is given in Figure 8.

Figure 8. FANUC collaborative robot equipped with DCS (Dual Check Safety)safety system for tracking position and speed [37-39]

The system has provided an automatic repetition of the robot's movement after the robot is stopped, at a speed depending on the space the worker is in, and in order to avoid delays. Safety is also ensured in the event that the worker's hand gets between the robot's axes, so that it does not get pinched and injures the worker. FANUC collaborative robots are equipped with ultra-safe protection to prevent contact. The protection is based on the proven disruptive technology of

Industry 4.0, i.e., smart sensor technology. Due to the protection of workers and the increased need for adequate protection of people from safety risks associated with industrial robotic systems, i.e., ensuring overall safety, an international and European standard was developed that covers safety requirements for industrial robots EN ISO 10218:2011 – ''Robots and robotic devices – Safety requirements for industrial robots'', which must be met by all robots that are implemented in production processes [40].

In relation to the first-generation industrial robots (about 64 % currently implemented in production processes), the second-generation industrial robots – collaborative robots have a number of advantages, some of which are:

- The worker works safely in the robot's workspace (robot and worker work together),
- The second-generation industrial robots – collaborative robots are characterized by simple and easy-to-handle tasks,
- By implementing the second-generation industrial robots – collaborative robots, it is possible to significantly improve performance, when operations are divided between workers and robots,
- By implementing the second-generation industrial robots – collaborative robots, we have the possibility of various levels of automation in the production process, so that we can partially automate tasks in those cases when complete automation is too complex or not economical,
- We can significantly improve non-ergonomic workstations using collaborative robots, but we must keep in mind that worker safety is an absolute prerequisite,
- The second-generation industrial robots – collaborative robots have the most significant role in Industry 4.0, which connects the real-life factory with virtual reality, thus opening future perspectives in global production,
- In order to ensure a reduction of the product life cycle and increase the variety of products, automation flexibility is required, which will result in an increase in the use of collaborative robots, prepared for use of applications that are increasingly popular with customers, which will result in an increased use of collaborative robots in small and medium-sized companies.

Companies have the following motives for the implementation of the second-generation industrial robots – collaborative robots: reduction of operating costs, reduction of capital costs, improvement of product quality and consistency, improvement of work quality for workers, respect of health and safety rules, increase of production rate, increase of flexibility in product production, saving space, etc.

3. Implementation of industrial robots with a special focus on the second-generation industrial robots – collaborative robots and service robots

In order to provide a layout of the implementation of both first-generation industrial robots and advanced robots, that is, second-generation industrial robots, it is necessary to analyze the trend of the implementation of industrial and service robots in the world for the period 2010-2021. The statistical data for the number of industrial and service robots were obtained from the from the International Federation of Robotics (IFR), the UN Economic Commission for Europe (UNECE) and the Organization for Economic Cooperation and Development (OECD) [41-43]- The data are graphically shown in the Figure 9.

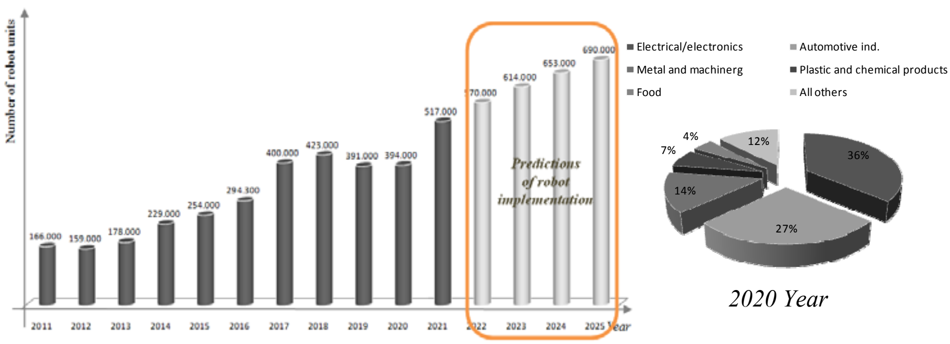


Figure 9. The trend of implementation of industrial robots in the world on an annual basis for the period 2011-2021 and the estimates till 2025

Based on the trend of the use of industrial robots in the period 2011-2021, shown in Figure 8, we can conclude that it has a growing character, from 166.000 units used in 2011 to an increase in the use of industrial robots until 2018. In 2019 and 2020, there was a decline in the use of industrial robots due to the Covid-19 virus pandemic. Slightly fewer industrial robots were used compared to the previous year: in 2019 391.000 robot units were applied, and in 2020 there were 394.000 units of robots. After the end of the pandemic, there was an increase in the trend of the implementation of industrial robots, and in 2021, 517.000 units of robots were applied. Based on the diagram shown in Figure 5, we see that in the period from 2021-2025, an increase in the implementation of industrial robots is predicted every year, with estimates of about 690.000 industrial robot units implemented by 2025. The highest implementation of industrial robots of both the first and second generation in 2020 (Figure 8) was recorded in the electrical/electronic industry with about 36 %, followed by the automotive industry with about 27%, metal industry and machines with around 14 %, plastic and chemical industry with around 7 %, and food industry with around 4 %.

Figure 10 shows the trend of the total implementation of industrial robots in the world [41-43].

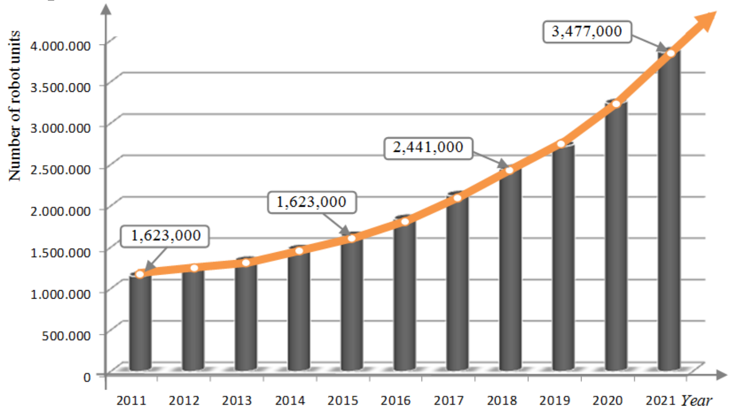


Figure 10. The trend of the total implementation of industrial robots in the world in the period 2011-2021.

The analysis of the total number of installed industrial robots in the world in the last ten years has shown that trend is increasing, and the increase demonstrates the exponential function. In 2011, there were 1.153 million units of industrial robots installed, in 2015 there was an increase to 1.623 million industrial robot units, in 2018 an increase to 2.441 million robot units,and in 2021 an increase to 3.477 million units of industrial robots implemented in the world. The conclusion is that the increase in the implementation of industrial robots in the world increased about three times in just ten years. The total amount of robot units includesthe second-generation industrial robots, also called collaborative robots. Due to their many advantages, their implementation increases on annual basis, a trend of which is shown in Figure 11 [9,41-43].

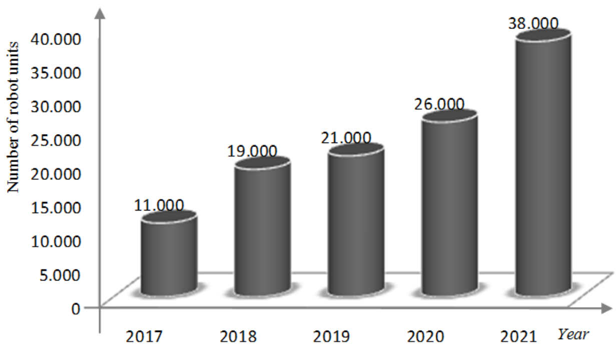


Figure 11. The trend of the implementation of the second-generation industrial robots – collaborative robots in the period 2017-2022

The second-generation industrial robots use the basic technologies of Industry 4.0. They are equipped with smart sensors and designed for direct work by interacting with workers within a common defined workspace. Based on Figure 10, we can see that their application is increasing every year, and in 2021 it reached the implementation of around 38.000 units of collaborative robots [24,26,29]. The very implementation of Industry 4.0 will enhance the implementation of collaborative robots in the coming years, since greater safety is ensured for workers. If a worker's hand stuck between the robot's axes, the worker would not be pinched and injured. Industrial robots of the second generation have a number of advantages compared to the first-generation industrial robots, some of which are:

- the second-generation industrial robots are characterized by ease of handling,
- by using the second-generation industrial robots, we are able to improve performance when performing operations between robots and workers,
- the work of the robot and the worker takes place in the joint work space, and the worker is safe from injuries,
- we are able to create various levels of automation with the second-generation industrial robots, which means that we can partially automate tasks in those cases when complete automation is too complex or not economical,
- the reduction of the product life cycle and the increase in the variety of products require the flexibility of automation, which will result in the increased use of the second-generation industrial robots,
- small and medium-sized enterprises will be able to implement the second-generation industrial robots for two reasons; the first is that the price is acceptable (very low compared to the first-generation industrial robots), and the second is that the implementation is simplified – no highly educated personnel are needed,
- non-ergonomic workstations can be significantly improved using the second-generation industrial robots, and we must keep in mind that worker safety is an absolute prerequisite,
- the second-generation industrial robots have the most significant role in Industry 4.0, which connects the real-life factory with virtual reality, thus opening up future perspectives in global production.

In order for the company to be competitive on the global market, it is inevitable that it moves towards the implementation of Industry 4.0, which will result in an increase in the use of industrial robots of the second generation [34-36]. When applying the second-generation industrial robots, companies have the following motives: reduction of operating costs, reduction of capital costs, improvement of product quality and consistency, improvement of work quality for workers, respecting health and safety rules, increase of production rate, increase of flexibility in product production, saving of space, etc. It is to be expected that the trend of using collaborative robots will be growing in the future. It is known that Industry 4.0 is being implemented in many world companies that are at the top of the global market, so that in the coming years the trend of implementing industrial robots in all industries will be continuously increasing [17,20,21-23]. In order to obtain actual information of the implementation of industrial robots in the world, we must analyze the implementation of industrial robots in the top ten countries in the world in 2020, as shown in Figure 12.

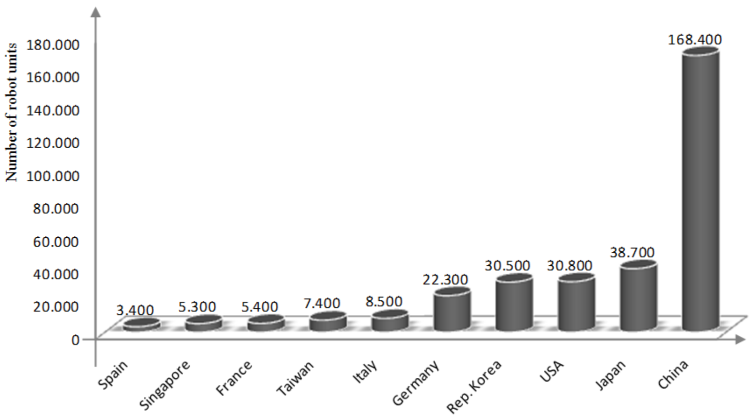


Figure 12. Trend of the implementation of industrial robots in the top ten countries in the world in 2020 [44]

The analysis of the implementation of industrial robots in the world in 2020 shows that the top ten countries are as follows (listed from lower to greater implementation of robots): Spain (3.400 robot units), Singapore (5.300 robot units), France (5.400 robot units), Taiwan (7.400 robot units), Italy (8.500 robot units), Germany (22.300 robot units), Republic of Korea (30.500 robot units), USA (30.800 robot units), Japan (38.700 robot units) and China (168.400 robot units). We can conclude that China holds the first place with a total of 42.74 % robots out of the total amount of robots implemented in 2020. Ever since 2014, China has been in the first place in terms of the implementation of industrial robots in the world, and we have already stated the reasons [34]. In order to provide a real state of the automation of production processes, the number of implemented robots in a country is not enough. We need to analyze the density coefficient of industrial robots per 10.000 employed workers in the production processes of a country's industry. An analysis of the coefficient of density of robots per 10.000 employed workers in the production processes of the industry was made for ten top countries: Spain, Singapore, France, Taiwan, Italy, Germany, Republic of Korea, USA, Japan and China, and is shown in Figure 13 [20,21,24,44]. The analysis of diagrams in Figure 13 has provided us with the conclusion that the world average of the robot density per 10.000 employed workers in the production processes of industry is 126 units of industrial robots. All ten top countries with the largest implementation of industrial robots in 2020 have a ratio of robot density per 10.000 workers higher than the world average. We have to single out China, whose robot density per 10.000 employed workers in industry was 246 units of robots, which is about 2 times higher than the world average. This is an amazing result, having in mind that only 10 years ago the robot density per 10.000 employed workers in industry in this country was negligible and far below the world average. It can be concluded that China invests a lot in robotics technology, thus demonstrating that they want to implement their strategy called ''Made in China 2025'' as soon as possible.We can see that China is the first in the world to apply for patents in robotic technology, and the first in the implementation of industrial robots [25,31,32].

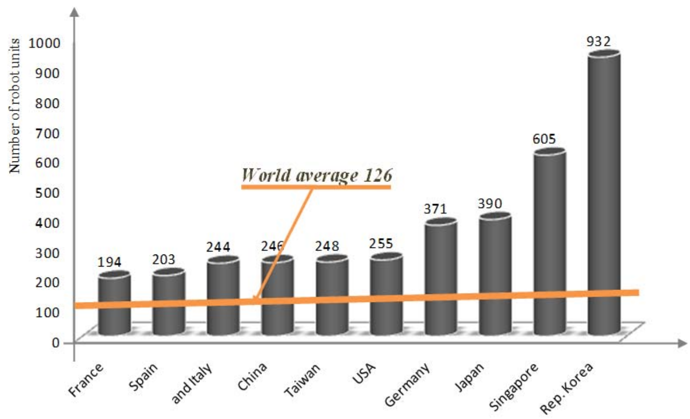


Figure 13. Density of industrial robots per 10.000 employed workers in production processes in the top ten countries in the world with the largest implementation of robots in 2020

The first five top countries in terms of the density of robots per 10.000 employed workers in industry in the world are the USA (density of 255), Germany (density of 371), Japan (density of 390), Singapore (density of 605) and the Republic of Korea (density of 932). Here we can single out two countries, Singapore and the Republic of Korea, which have the world's highest ratio of robot density per 10.000 employed workers in industry, which means that they are the countries with the highest automation of production processes in the world. We must mention that in the next few years, China will also be among the top five countries thanks to its investment in robotics technology. In addition to the implementation of industrial robots in production processes, the development of new technologies, especially robotic technology, leads to the implementation of service robots for professional use in production processes. We have conducted an analysis of the implementation of professional service robots and service robots for logistics in the period 2011-2021, which is presented in Figure 14 [25,38,44].

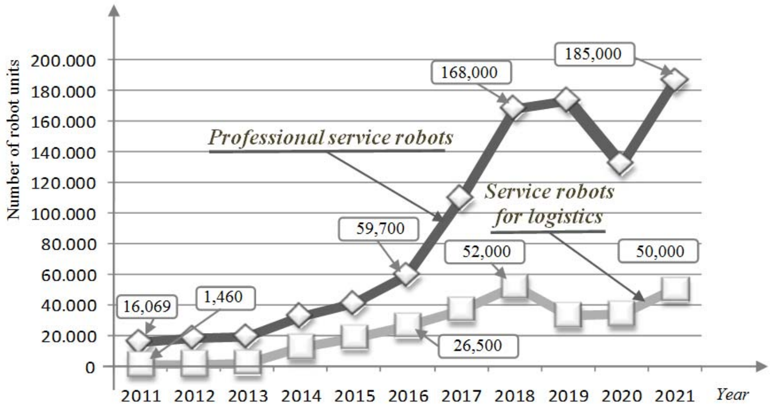


Figure 14. Diagram of the trend of implementation of professional service robots and service robots for logistics in the world in the period 2011-2021

The analysis of the diagram in Figure 14, provides a conclusion that from 2011 until 2018, the growth trend of the implementation of professional service robots takes place according to an exponential function, and from 16.067 robot units implemented in 2016, the implementation increased to 168.000 robot units in 2018. This growth trend is due to the implementation of Industry 4.0 in production processes in companies worldwide, that want to be competitive on the global market. They can achieve this only by implementing the basic technologies of Industry 4.0. One of the main technologies for automation of production processes is robotic technology, i.e., industrial and service robots. The largest number of professional service robots used in the industry is service robots for logistics, whose growth trend shows a mild exponential function in the period 2011-2018, with 52.000 robot units implemented in 2018. During the Covid-19 virus pandemic in 2019 and 2020, there was a slight decrease in the implementation of both professional and service robots for logistics. However, in 2021, following the end of the Covid-19 virus pandemic, the implementation of these robots begins to increase, so that professional service robots have reached application of about 186.000 robot units, and service robots for logistics about 50.000 robot units. It is expected that the use of these robots will increase abruptly in the coming years, and the reason for such expectations lies in the fact that companies in developed countries are implementing Industry 4.0 on a large scale, while companies in developing countries are also trying to catch up with the implementation of Industry 4.0, which means increasing the implementation of both industrial and service robots. As we have seen, many companies in the world are increasingly implementing robots, whose main aim is to remain competitive in the global market. Companies for research, development and implementation of robotic solutions offer new advanced robotic solutions every year precisely thanks to the technologies of Industry 4.0. In the recent years, artificial intelligence has been implemented in advanced robotic solutions, which is currently almost in the first place in the research technology of Industry 4.0. For the sake of illustration, we will interpret a couple of advanced robotic solutions from companies that deal with the implementation of advanced robotics.

The Japanese FANUC group provides products and services for automation by implementing robots and wireless systems for computer control. They have developed different collaborative robots that work directly with humans. Collaborative robots take on boring repetitive tasks, lifting up to 35 kg, thus maintaining the health and safety of your workers while automating entire assembly lines. They are intended to perform a number of tasks in production processes such as: AI visual inspection, quality control, arc welding, machine maintenance, palletizing, guided vision selection and placement, finishing, grinding, assembly, machine servicing, circuit suppliers, monitoring and inspection in production processes, and much more. For the sake of illustration, Figure 15 shows the implementation of FANUC collaborative robots for performing certain tasks [46,47].

Figure 15. Implementation of collaborative robots in the production processes of Fanuc Company

Collaborative robots are safe and flexible. Their implementation improves the production process, saves space, reduces costs, and they have to possibility to automate tasks that could not be automated until now. They are equipped with a wide range of sockets, so it is easier for the robot to cooperate and change to perform different tasks. It is designed to eliminate injuries and avoid collisions when working side by side with people. The possibilities of collaborative robots are endless. The American robotics company Boston Dynamics developed and implemented the agile Spot robot which is also called a half-dog or half-cyborg robot that is capable of working independently and performing a large number of tasks.Spot robot is a four-legged robot that can climb stairs and navigate difficult terrain, which gives it an advantage and allows it to be the perfect tool for surveying dangerous and inaccessible environments, as well as being able to collect data from different locations. It is designed for working and maintaining a very professional relationship, aimed at contributing to the productivity of companies, and designed for detection, inspection and remote management. The basic characteristics of the Spot robot are:

- it moves at a speed of 5.67 km/h,
- it can lift a load of 14 kilograms,
- it includes a replaceable battery, with autonomy of up to 90 minutes,
- it is resistant to rain and dust, but cannot be immersed (played) in water,
- it works at temperatures between -20º and 45º,
- it has sensors and cameras that allow a 360-degree view,
- it is foldable and can be stored, takes up less space,
- it has a possibility of adjustment and improvement by third parties.

Owing to its sensors and cameras, Spot can open doors, go up and down stairs, lift loads and even inspect difficult environments such as gas, oil and energy plants, as well as construction sites. It uses stereo cameras to avoid obstacles and people as it moves through dynamic workplaces. It is equipped to enable remote viewing. In case of a fall, Spot can even stand up independently.

The largest Australian natural gas producer Woodside has implemented an agile mobile Spot robot for inspection and autonomous detection of gas leaks through holes as part of routine maintenance, which has great advantages for plant safety in the oil and gas industry, as shown in Figure 16 [48,49].

Figure 16. Boston Dynamic agile mobile robot SPOT for industrial plant inspections

Gas processing plants are complex, potentially dangerous places, with a number of equipment that must be continuously monitored and inspected. Every company with a processing plant has its own priorities: safety, reliability and efficiency of its operations. Since safety is the main priority in the oil and gas industry, the implementation of the agile Spot robot will enable operators to maintain their facilities safely and efficiently. Figure 16 shows the agile Spot robot performing an inspection of facilities in the oil and gas industry. Robot Spot has been implemented for a range of autonomous inspection applications, including anomaly detection, thermal inspections and meter reading. In the inspection industry, Spot is equipped with an array of sensors to collect data to monitor asset condition and plant safety. These payloads include the Spot CAM+IR for visual and thermal inspections and the FLIR MUVE C360 sensor for gas detection and analysis. Spot is also equipped with an Enhanced Autonomy Payload (EAP) to improve the robot's autonomous navigation capabilities and an LTE modem for constant communication. Every 12 hours, it conducts an inspection along the same route through the plant and assesses awareness of the situation.

Figure 17. Implementation of Boston Dynamic Spot agile robot that assist in the treatment of patients suffering from the COVID-19 virus [50-51]

The Spot robot will record things that we may not notice or that we are not always there to see. Likewise, agile Spot robot is used in medical institutions to help doctors treat patients with the COVID-19 virus, as shown in Figure 17.
Doctors use it to evaluate people who think they have symptoms of the COVID-19 virus. They use a robot to measure patient's vital signs from a distance of two meters. The robot is equipped with cameras and a tablet, and uses computer vision technology. Doctors are able to measure the patient's skin temperature, breathing rate, blood oxygen saturation and pulse without being in the same room as the patient. An algorithm was developed that, using an infrared camera, enables measurement of elevated skin temperature and breathing rate, while the camera measures the temperature of the skin on the face. The algorithm then correlates this temperature with the core body temperature and determines the body temperature. Likewise, as the patient breathes in and out while wearing the mask, their breath changes the temperature of the mask, so measuring this temperature change allows researchers to calculate how fast the patient is breathing. The algorithm also takes into account the ambient temperature and the distance between the camera and the patient, so that measurements can be taken from different distances, under different weather conditions, and still be accurate. Spot Robot is equipped with three monochrome cameras that filter different wavelengths of light – 670, 810 and 880 nanometers. These

wavelengths allow researchers to measure small color changes that occur when hemoglobin in blood cells binds to oxygen and flows through blood vessels. The researchers' algorithm uses these measurements to calculate pulse rate and blood oxygen saturation. Boston Dynamics researchers have tested and measured the robot on healthy volunteers and now plan to test the approach on people showing symptoms of COVID-19 in a hospital emergency department. In the long term, the team envisions that robots could be deployed in patients' hospital rooms.
It is known that the Swiss company ANYbotics was founded in 2016 (in 2009 it already made the first prototype robot) to push the boundaries of advanced robotics, so that a new way of managing production processes can be created. The historical development of robots for automating inspection in production processes in industry is shown in Figure 18 [52].

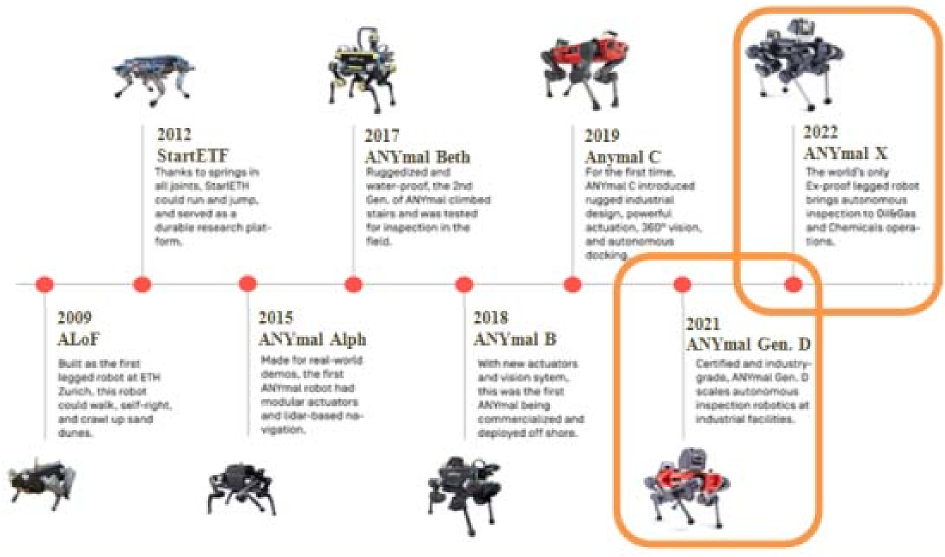


Figure 18. Historical development of the ANYmal service robot from the ANYbotics Company

Based on Figure 1P, we see that the first prototypein 2009was named AloF. The research and development of the robot has improved every year, so in the last two years they have developed a robot for monitoring and inspecting an industrial plant, namely ANYmal Gen. D in 2021 and ANYmal X in 2022. The robots are equipped with a visual camera that captures clear images and videos at long distances. In addition, it is also equipped with a thermal camera that provides precise temperature readings in the range of -20–500°C without physical interaction. Furthermore, it is equipped with a directional microphone for recording acoustic measurements in the sonic and ultrasonic frequency range, as well as an LED reflector that is used in low-light conditions to support visual inspections. It has a pan-tilt unit that uses long-range movements together with the movement of the robot base to position sensors to check hard-to-reach places.

Figure 19. Autonomous mobile robot ANYmal from the ANYbotics Company for industrial plant inspections [52]

These are built-in sensors that record the environment around the robot for smooth navigation. It is also equipped with a computer that performs computer analysis and sensor reading protocols, eliminating the need for continuous network communication. The ANYmal robot of the latest generation from the ANYbotics Company is shown in Figure 19. We must note that the legs of the ANYmal robot provide incomparable mobility when moving up and down stairs, climbing over obstacles, steps and gaps and crawling into narrow spaces. It provides reliable performance in harsh indoor and outdoor environments and through rain, water spray, wind, snow and dust, as shown in Figure 19. ANYmal's industrial plant inspection robot provides visual, thermal and acoustic insight to monitor the condition of equipment and infrastructure. Inspection algorithms based on artificial intelligence, which analyze sensory data to interpret values, classify results and detect anomalies. If necessary, we can always take control and manage the ANYmala robot manually. We can use the cameras to see in front and back of the robot, so we can navigate it. By using the ANYmal robot, we are able to automate the review and inspection of the production process from start to finish, because in this way we provide information to the operators of the production processes in order to maximize the uptime of the equipment and improve safety while reducing costs. Many companies in the world are researching and developing service robots for logistics, the implementation of which has increased to the maximum in recent years precisely because of the implementation of advanced Industry 4.0 technologies. Thus, the Danish company MiR-Mobile Industrial Robots has developed a large number of service robots MiR 100, MiR 250, MiR 250 Hook, MiR 600, MiR 1350, MiR 1350 EU Pallet Lift, which are used for logistics in production processes and warehouses, as shown in Figure 20 [53].

Figure 20. Design versions of service robots for logistics from the Danish company Mobile Industrial Robots MiR

Prior to the introduction of service robots for logistics, transportation in production processes was conducted manually. MiR service robots are collaborative and autonomous: they safely maneuver around all kinds of obstacles. If a person steps out in front of them, they will stop. Advanced technology and sophisticated software enable the robot to move independently and choose the most efficient route to the destination. When they detect an obstacle, they automatically move around it and can swerve to change their path to avoid stopping or delaying the delivery of material (Figure 21). The service robots are equipped with the latest laser scanner technology and provide a 360-degree visual display for optimal safety. The front 3D cameras have a range from 30 to 2000 mm above floor level and two sensors in each corner. These sensors ensure that the robot can see pallets and other obstacles, which it normally can barely see.

Figure 21. Examples of implementation of service robots for logistics in production processes and warehouses [53]

Service robots consume energy from the battery during operation. After the battery is discharged, it needs to be recharged. Battery charging connectors are installed in the workspace, so the service robot reaches the connector and turns on to charge the battery. When the battery is charged, the robot is ready to process the next order. The batteries have all the advantages of lithium-ion battery technology, they have a long life (about 1000 cycles) and very low self-discharge (<5%/month). The implementation of industrial robots will increase in the coming years. It is expected that the second-generation industrial robots – collaborative robots and service robots will be implemented more than the first-generation industrial robots.

4. Conclusion

Implementation of disruptive technologies of Industry 4.0 technologies such as Internet of Things (IoT), advanced robotics, smart sensors, Big Data, analytics, cloud computing, 3D printing, machine learning, Virtual and Augmented Reality (AR), Artificial Intelligence, and productive maintenance are changing production processes and organization of production and sales. The disruptive technologies of Industry 4.0 are bringing disruption to almost every industry in the world, because they have a bigger impact than we think. The impact is reflected on all segments of society as well as on small, medium and large companies. The implementation of Industry 4.0 relies on advances in the use and sharing of information and has the potential to connect almost everything on the web, which dramatically improves the efficiency of the company. By applying Industry 4.0 in the production processes of all branches of industry, the linear production process is transformed into a network production process. In other words, with all the mentioned technology, it turns into a closed-loop production process, where we have complete information about production at all times. The introduction of disruptive technologies enables companies to process and store data, and improves the design, production and delivery of their products more efficiently. Here are some of the advantages of the disruptive technologies of Industry 4.0:

- Companies will improve the business process,
- It will reduce operating costs.
- Increased productivity of companies,
- They have expanded access to the global economic market (broad customer base),
- Provides companies of all sizes with greater outsourcing opportunities (external cooperation),
- Companies will improve cooperation among themselves, as well as between departments and individuals, thanks to the availability of new communication tools;

- Advanced development, such as blockchain technology, greatly increase the security of business and personal data.

As we have seen, the disruptive technologies of Industry 4.0 such as: IoT (Internet of Things), advanced robotics, Cloud Computing, smart sensors, Radio Frequency Identification, Cyber-Physical Systems and Big Data, are crucial in the application of the concept of Industry 4.0, because they imply complete digitization of all production processes, including the process of creating a product idea, product engineering, production organization, process control and the provision of industrial services. We have also indicated how governments and political parties use disruptive technologies in the country to control information, suppress basic human rights, discredit political opponents and override dissent. Therefore, it is necessary to establish a smart regulation that refers to the answers to the problems of coordination and knowledge by being more interactive and involving more stakeholders, including interest groups. The development of advanced robotics led to second-generation industrial robots – collaborative robots.

The analysis concluded that the implementation of industrial robots of the first and second generation, as well as professional service robots, has continuously increased in the last ten years worldwide. Here we must note that advanced robotics is continuously developing, especially collaborative robots. It is estimated that their implementation will continuously increase. In the recent years, the implementation of service robots for professional use, especially service robots for logistics, has increased rapidly, as robotics companies have developed second-generation robots and fully autonomous logistics systems. Companies that implement advanced robotics in their production processes have great advantages, some of which are:

- Reduction of capital costs,
- Increased production rate and profitability,
- Increased flexibility during production,
- The possibility of automating certain operations in the production process, so that tasks can be partially automated in cases where complete automation is too complex or not profitable,
- Improving the quality of employees' work, while respecting health and safety rules,
- Continuous improvement of product quality,
- Reduction of material waste and increase in productivity,
- Transformation of rigid automation into flexible automation,
- Saving space in production areas,
- In the implementation of Industry 4.0, industrial and service robots play the most important role in connecting the real-life factory with virtual reality, which opens greater prospects for implementation in global production,

- Non-ergonomic workstations can be significantly improved with the help of robots, always keeping in mind while that worker safety is an absolute prerequisite,
- Increased product variety and reduced product life cycle require flexible automation, which will result in increased use of collaborative robots, etc.

The goal of every company present in the global market today is to achieve and receive the benefits that can be gained by implementing next-generation industrial and service robots. By using a large number of smart sensors in the production process, we always have information about production devices and machines, based on which we decide when to replace devices and machines, which enables permanent maintenance. There are three main challenges when it comes to the application of advanced robotics, both collaborative robots and service robots. The first challenge relates to methods and methodology, especially how to integrate machines and devices with an advanced robot. The second challenge is education, that is, how to prepare new generations of engineers who need to work and implement Industry 4.0. The third challenge is related to the society, primarily how to explain to people that Industry 4.0 creates new opportunities and brings a better quality of life for all of us, without being afraid of changes and everything that Industry 4.0 brings.

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