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SAFETY AT WORK WITHIN INDUSTRY 5.0 - QUO VADIS

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SUMMARY: All EU nations and the rest of the globe have been undergoing a massive digital transformation since Germany introduced and put into practice the Industry 4.0 concept in 2011. This entails not only boosting production by incorporating all current means of production, such as modern ICT solutions and robotics, but also introducing new expert profiles and ways of working. And, as that process became increasingly intensive, a new phrase, Industry 5.0, emerged in 2015. This concept focuses on the human potential as well as various IoT and Big Data applications to enhance human job and talent. Its objective is to connect individuals who work with robots in automated industrial settings. It is obvious that protecting worker safety and wellbeing at work entails not just maintaining physical health but also maintaining mental health, autonomy, dignity, privacy, and inclusion. Thanks to new technologies and the concept of Industry 5.0, we can have safer and more productive workplaces where the skills and creativity of workers come to the fore.

Key words: *Industry 5.0, human-centric approach, cobots, safety at work, inclusiveness*

INTRODUCTION

The term and concept "Industry 4.0" (I4.0), as a new strategy for the development of German industry, was presented at the Hannover Messe 2011 and announced as the beginning of a new 4th Industrial Revolution (4IR). It is promoted as a way to boost the industrial sector's competitiveness in Germany by integrating "Cyber-Physical Systems" (CPS) more deeply into manufacturing procedures *(Nikolić, 2017)*. Hundreds of years have passed between the previous three industrial revolutions, and this one has already arrived after half a century. The first was started in the 18th century by the energy of water and steam, which enabled a higher degree of mechanization (construction of the first loom powered by steam in 1784). The lower need for human labor and the dismissal of workers has caused great social unrest, workers' revolt and the destruction of these machines. In the 19th Century, electricity replaced steam energy, beginning the 2nd Industrial Revolution (construction of the first mechanized slaughterhouse in Cincinnati in 1870). The 3rd Industrial Revolution was marked by the use of electronic and information-communication systems, and on their basis the wide application of automation in production processes (application of the first Programmable Logic Controller in 1970). According to some authors *(Roser, 2015)*, I4.0 is not a new industrial revolution, but a continuation of the 3rd Industrial Revolution based on intensive modern technological development. But the fact is that this development based on modern information and communication solutions is so powerful that it deserves the term 4IR. Furthermore, each of the industrial revolutions brought a new attitude of employers toward workers, as well as a change in their place in society, in addi-

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tion to raising the intensity and lowering production costs. The emergence of I4.0 and the intensive robotization of production have also had a strong impact on the status of workers in production and society. And as this process became more intense, in 2015 a new term Industry 5.0 (I5.0) appeared *(Nikolić, 2017, Croatian Chamber of Commerce, 2022, Roser, 2015)*.

The aim of this paper is to analyze the characteristics of I4.0 and the shifts brought by I5.0, their differences, connections, as well as the impact on the status of workers from the perspective of safety at work.

METHODS

The applied research methodology includes the analysis of available written and online sources. The collected data is also supported by our own experiences gained through researching accelerated digital transformation (DT) during the COVID-19 pandemic in Croatia and the world *(Kralj & Mehmetaj, 2022)*.

CHARACTERISTICS OF INDUSTRY 4.0

As stated in the introduction, I4.0, also known as the 4IR, denotes a shift in the way people live, work, produce, and manage business and public resources. The path of technological adaptation to the realization of this concept is called DT. DT relies on the accelerated development of information and communication technology, but there are also changes in people's understanding of the necessary changes in all segments of activity, as well as changes in curricula, which must create new staff to support the realization and sustainability of this concept *(Kralj & Mehmetaj, 2022, Franc & Dužević, 2020)*. The impacts of this concept on companies are basically: localized and identified production series that provide more knowledge about the production process; connectivity within the organization; adaptability and ability to optimize the production process through continuous collection of external and internal data; competitive advantage; individualization of production according to customer requirements and greater connection with customers. From the perspective of workers, the impacts are: additional requirements for employees, training (IT knowledge); greater involvement in the innovation process; a new kind of human-machine interaction with less worker presence inside the factory; support for smart assisted systems; decentralized structures and governance forms; more decision-making space. Organizational connectivity is crucial and is based on vertical and horizontal integration. Vertical integration implies networked production systems that approach changes in the production process through alternative strategies.

The regulatory framework for vertical integration is the "Smart Factory". Production blocks will no longer be static and predetermined *(Croatian Chamber of Commerce, 2022)*. IT configuration rules will be defined from which a specific production structure will be created. Horizontal integration implies optimized flow of raw materials and information from different suppliers in the global value chain to end users. Connected IT systems monitor the needs for raw materials in all steps at the global level. Based on the information, they can create production plans and thus forward requests to suppliers in real time for components and raw materials for production *(Croatian Chamber of Commerce, 2022)*. The technological solutions and trends on which the above functionalities of I4.0 are based, ranked in order of importance, are: Internet of Things (IoT); big data analytics; additive technologies (3D printing with various materials), advanced (autonomous) robotics; smart sensors; augmented reality; cloud computing; energy storage; artificial intelligence; nanotechnology; synthetic biology; simulation; man-machine interface; mobile devices; cyber security; quantum computation. IoT has many different definitions, and one of the shortest is the global network that connects smart things *(International Telecommunication Union, 2012)*. It is a collection or set of things (objects or devices) that can be monitored and provide information wirelessly over the Internet utilizing the most common monitoring or management mobile application. In addition to communication, it includes devices, infrastructure and applications. The offer of applications to users takes place using software platforms (IoT platforms) that integrate things and continuously collect their data. This necessitates the processing of massive amounts of data (Big

Data), typically in real time, as well as the consolidation and recording of data from various sources in a unique manner. The leading new paradigm is machine-to-machine (M2M) communication. Not just between machines in the factory, but communication between all existing devices and systems. The industry is believed to have several reasons for introducing networked software into machines and products in the classic industrial division of design, production, and support of products and services. Artificial intelligence and robotics are an integral part of current and upcoming changes. Today, an industry without the application of robotics is unthinkable. The term CPS refers precisely to the intensive use of intelligent robots and forms the main production backbone of the "Smart Factory" concept (Figure 1); (Toyota Motor Company).

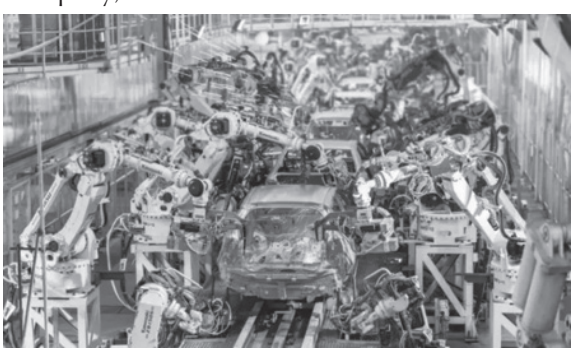

Figure 1. Application of robots in the auto industry
Slika 1. Primjena robota u autoindustriji

In previous applications, robots have usually been in cages or behind workstation fences. Changing their position and role is a fundamental idea of the coming changes i.e., it is believed that intelligent machines that learn independently, that are adaptable and can take into account their environment, should naturally cooperate with people. According to the vision of the 4IR, robots and humans should work together and perform tasks. It should be emphasized that although robots are given a greater role, the central idea is that they adapt to humans, not the other way around. Robots are expected to have the following capabilities: locating and navigating, computer vision, adaptive planning, multiagent strategies. Larger robotic systems play an important role in a number of industrial activities, from the automotive industry to the biotechnology sector. Another change brought about by DT is the way data is collected. For many years, companies have made decisions based on information obtained from a variety of traditional sources, including production reports, internal reports, market research studies, and so on. Today, there are many more available data sources, including data generated by sensors in smart products, as well as data from Internet search engines or social media. Big Data Analytics opens up new opportunities for companies in the form of advertising that allows them to stay on top of current trends and opportunities in international markets without having to invest significant resources in local marketing, as well as more efficient procurement, production, and distribution. The ability to process and analyze this collected data for further use is exactly what makes this technology very valuable. However, it should be emphasized that a prerequisite for the functioning of these systems is good broadband Internet coverage, the unavailability of which is a major brake on DT in less developed countries. Three-dimensional (3D) printing has revolutionized the way products are manufactured and delivered. Traditional production processes are subtractive, which means that the material is removed from the workpiece using proper equipment, resulting in the shape of the given object. Parts and components are assembled to create the final object. In contrast, 3D printing is an additive process by which an object is obtained by laying different layers of material in succession. Products can be better adapted to the needs of end users as 3D printing allows the production of small quantities in a much shorter time with optimization of material consumption and no waste *(Croatian Chamber of Commerce, 2022, Kralj & Mehmetaj, 2022, Franc & Dužević, 2020)*. It is true that this industrial revolution is also creating a surplus of labor within certain occupations. But on the other hand, it creates new jobs in professions that include the development, management and application of smart systems. Figure 2 shows one example of new human-machine interfaces, which require these new job profiles. For this purpose, it was necessary to adjust the education, which is intensively focused on STEM (science, technology, engineering and mathematics) areas starting from primary education.

Figure 2. Human-machine interaction: robot behavior programming

Slika 2. Interakcija čovjeka i strojeva: programiranje ponašanja robota

In the field of higher education, there is an insistence on innovative projects of university entities that must be brought to a prototype ready for use in the economy or the creation of new start-up companies *(Nikolić, 2017)*. The emergence of the COVID-19 pandemic has significantly accelerated all these changes in the economy, public services and education. Enormous efforts have been made to digitize all of these systems almost overnight and bring them closer to the ideal of I4.0. In fact, the development took place in order to adapt and survive in the new situation. In terms of humanity, society has become almost completely contactless *(Franc & Dužević, 2020, Dervojeda, 2022)*. Critics of I4.0 point out that technological advances and robotics have led to new forms of alienation and exploitation of workers (robots dictate the pace of work) with the goal of intensively increasing production and capital. Education is focused on the use of advanced systems for learning management and distance communication. They believe that I4.0 brought complete "dehumanization", the rise of technology above man and the consequent alienation *(Dervojeda, 2022, European Commission, 2021)*.

WHAT DOES INDUSTRY 5.0 BRING

First of all, it should be noted that the development of I5.0 or the 5IR is still based on intensive technological development and improvement of information and communication systems defined in the concept of I4.0. However, instead of taking new technology as a starting point and examining its potential to increase efficiency, the human-centric approach puts fundamental human needs and interests at the heart of the production process. Instead of wondering what we can do with new technology, we wonder what technology can do for us. Instead of asking industry workers to adapt their skills to the needs of rapidly evolving technology, we want to use technology to adapt the production process to the needs of workers e.g., to guide and train them. It also means ensuring that the use of new technologies does not jeopardize the fundamental rights of workers, such as the right to privacy, autonomy and human dignity. A worker for a company is no longer a "cost" but an "investment". This means that the employer is interested in investing in the skills, abilities and well-being of its employees, in order to achieve its goals. Clear boundaries are being lost between the so-called white and blue collars. In addition to human-centric orientation, I5.0 must adhere to the concepts of sustainability and resilience. Resilience refers to achieving a higher degree of robustness in industrial production i.e., prevention of disturbances and providing support to critical infrastructure in times of crisis. Crises, such as the COVID-19 pandemic, have highlighted the fragility of our current approach to globalized production. This approach should be balanced by the development of sufficiently resilient strategic value chains, adaptable production capacities and flexible business processes, especially where value chains serve basic human needs, such as health care or security. So, the three key factors of Industry 5.0 are: a human-centric approach, sustainability and resilience *(European Commission, 2021)*.

In terms of production workers, some authors *(Østergaard, 2022 [a], Rada, 2022)* argue that after the industry is reorganized according to the I4.0 paradigm, even the small number of workers that remain would work like machines. They agree that man should be returned to industrial production with the use of new techniques such as collaborative robots (cobots). For example, company “Universal Robots” has embraced this concept in response to large companies focused on I4.0, and their robots have become the most widely accepted collaborative robots. The company points out that I5.0 is more "anti-industrial" than

industrial, because it is a return to the time before industrialization, a return to a time when skills and crafts were valued, when each product was unique according to the customer's wishes. Over time, it has become widely accepted that I5.0 is a new type of human-robot collaboration that takes advantage of both machines and humans' talents. I4.0 achieved the sale of goods to a known customer prior to production, and I5.0 introduces the option of further bespoke production specifications *(Østergaard, 2022 [b])*.

Machines are more precise and with more power, and workers possess skills, as well as cognitive and critical thinking *(InfinityQS, 2022)*. This mode of operation is suitable for jobs that are between fully manual assembly and fully automated production lines. Working with cobots allows companies of any size to implement automation even in places where it is unprofitable or difficult to implement. This is supported by the growing desire of customers for personalized products according to their wishes and needs. This breakthrough into the processes of production through the collaboration of cobots and humans, some authors also call the revolution of "human touch" *(Østergaard, 2022 [a], Østergaard, 2022 [b], InfinityQS, 2022)*. It is believed that this is the return of workers to the production process, taking advantage of the benefits of automation and cognitive abilities of people. Cobots cannot be considered a revolutionary invention, but it is a logical evolutionary step in the development of robots. They are getting more and more sensors to be able to perceive the environment, recognize objects and their position in space, and the built-in higher level of artificial intelligence enables adequate decisions to be made. *(Østergaard, 2022 [b])* The concept of I5.0 was also reflected in the change of educational approach. Its purpose explicitly refers to the specific outcomes that people need to achieve as a result of a particular learning experience. It's not about handing out laptops or tablets to every student. It's not just about bettering infrastructure and connectivity. It's not about creating digital platforms and tools. Instead, it's about preparing students to be intellectually, socially, and emotionally strong persons, while also considering their health and personal development, as well as general motivation, creativity, and restoring students' joy of studying. Digital equipment, infrastructure, and platforms are still important, but only as drivers, not as the purpose itself. It is taken into account not only the needs of the market/company (employability), but also the needs of society and students. It provides "big picture education", emphasizing how the educational offer fits into the overall learning path, labor market, and global development, and students are viewed as change agents who are actively involved in curriculum development and implementation *(Dervojeda, 2022)*.

CONTRIBUTION OF I5.0 TO SAFETY AT WORK

Although the human-centric orientation of I5.0 represents a great progress in itself, here we will list some technical-technological solutions that will significantly contribute to work safety in practice. In addition to achieving greater job security, the goal is also the creation of universally designed workplaces that enable people with different motor and cognitive abilities to be included in the modern production society.

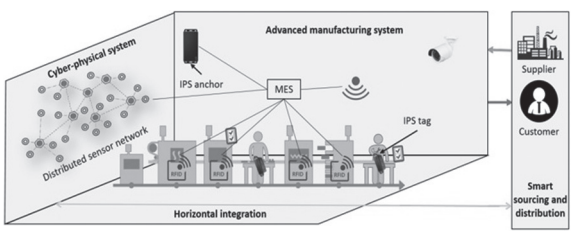

Figure 3. The concept of intelligent space - iSpace
Slika 3. Koncepcija inteligentnog prostora - iSpace

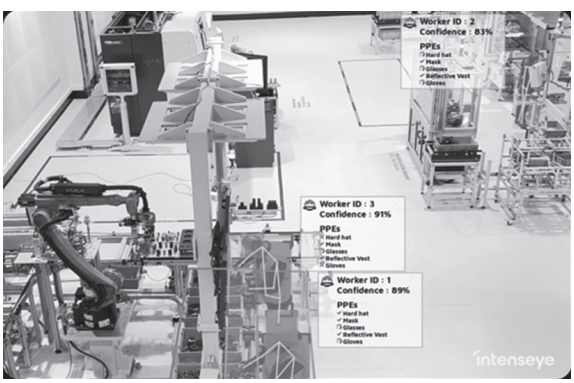

Figure 4. Surveillance cameras and AI in the service of safety at work- iSpace
Slika 4. Nadzorne kamere i AI u službi zaštite na radu - iSpace

In the framework of I4.0, the concept of intelligent space (iSpace) is defined as the control and communication backbone of the Smart Factory, which, thanks to advanced sensors and an internal positioning system (IPS) based on a wireless connection system, ensures the function of vertical and horizontal integration. Figure 3 shows the principle organization of the intelligent space. The i5.0 brings further progress of the iSpace system, based on the further development of intelligent sensors. Figure 4 shows an example of a concrete development of the iSpace concept, developed by the Turkish company Intenseye, where the use of personal protective equipment is monitored using surveillance cameras and artificial intelligence (AI). The system monitors and calculates the percentage of safety (confidence) of the work of an individual employee in the plant depending on how many required parts of the protective equipment the worker uses. In addition to protective equipment, the paths the workers take are also monitored, warning if they find themselves in a dangerous zone. It can be said that the system protects workers from themselves and possible bad habits. Figure 5 shows the detection of the use of personal protective equipment using AI with indication using augmented reality (AR).

Figure 5. Use of AI and AR in monitoring the use of protective equipment

Slika 5. Uporaba AI i AR u nadzoru korištenja zaštitne opreme

In order to further develop the human-centric approach, efforts are made to protect workers' health and extend their working life as much as possible, but also to make production workplaces accessible to workers with different personal and physical abilities. Bionic exoskeletons are an example of advanced CPS that achieve these goals by making workplaces more accessible, universally designed, and people with different physical and cognitive abilities easier to include in modern production processes. Figure 6 shows an example of exoskeleton application in the auto industry.

Figure 6. Use of exoskeleton in auto industry

Slika 6. Korištenje egzoskeletona u autoindustriji

Exoskeletons make certain tasks less physically demanding. They are definitely the highlights of advanced collaboration between human and machines.

CONCLUSION

I4.0 is a concept aimed at establishing "Smart Factories" in which all activities, from communications to production, are automated in order to maximize profit. Because the number of employees is decreasing and the structure of employees is changing, new knowledge, particularly in the field of informatics, is required. This concept is mainly intended for production plants that produce large quantities of products, which can be different, personalized, but use the same type of work technology. Because the end product is increasingly influenced by the customer's requirements, factories that generate high-volume products are evolving into factories that produce mass products. I5.0, on the other hand, focuses on the interaction between humans and machines. The collaborative work of humans and robots combines human creativity and skill with the speed, productivity and precision of robots in order to create new commercial and social values. I5.0 is human-centric and returns "human touch" to production. Although this concept of work can

be applied to huge industries, it is best suited to medium and small companies where full automation is not possible or cost-effective, and market demand is increasingly looking for products personalized to consumer preferences. There are some technological operations in large industrial businesses where full automation is neither cost-effective or very difficult, thus this type of collaborative work between cobots and employees is cost-effective. For instance, there is great potential for collaborative work in the field of plant maintenance. I5.0, according to certain critics and theorists, is not a significant upgrade to I4.0, nor even a new industrial revolution. However, based on the comparison of these two concepts presented, we can conclude that this is a significant organizational and production transformation that alters social and economic relationships and places the man-worker at the center while respecting his privacy, autonomy, and human dignity, as well as his true capabilities in order to be included in society and the economy. In fact, these are some of the most important characteristics of the industrial revolution.

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ZAŠTITA NA RADU U SKLOPU INDUSTRIJE 5.0 - QUO VADIS

SAŽETAK: Otkako je Njemačka 2011. uvela i u praksu stavila koncept Industrije 4.0, sve zemlje EU-a i ostatak svijeta prolaze kroz intenzivnu digitalnu transformaciju. To ne podrazumijeva samo jačanje proizvodnje uključivanjem svih trenutnih sredstava proizvodnje, kao što su moderna ICT rješenja i robotika, već i uvođenje novih stručnih profila i načina rada. Dok je taj proces postajao sve intenzivniji, nova fraza, Industrija 5.0, pojavila se 2015. godine. Ova koncepcija fokusirana je na ljudski potencijal, kao i na razne IoT i Big Data aplikacije za poboljšanje ljudskog rada i vještina. Cilj ove nove koncepcije je povezati pojedince koji rade zajedno s robotima u automatiziranim industrijskim sustavima. Očito je da zaštita sigurnosti i dobrobiti radnika na poslu ne podrazumijeva samo očuvanje fizičkog zdravlja, već i očuvanje mentalnog zdravlja, autonomije, dostojanstva, privatnosti i uključivosti. Zahvaljujući novim tehnologijama i koncepciji Industrije 5.0, može se osigurati sigurnija i produktivnija radna mjesta gdje vještine i kreativnost radnika dolaze do izražaja.

Ključne riječi: *industrija 5.0, humanocentrički pristup, koboti, zaštita na radu, uključivost*

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