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INDUSTRY 5.0 AS A NEW CONCEPT OF DEVELOPMENT WITHIN HIGH VOLATILITY ENVIRONMENT: ABOUT THE INDUSTRY 5.0 BASED ON POLITICAL AND SCIENTIFIC STUDIES

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Purpose: the aim of the paper is to present the frameworks of Industry 5.0 in a labile environment. Until the COVID-19 pandemic, the notion of a dynamic environment was used, due to the speed of the changes taking place in economies and society, which could be anticipated and proactive measures taken. The pandemic, whose impact was experienced worldwide, changed the environment, which took economies, societies and businesses by surprise. Such an unpredictable, unstable environment is called environmental volatility.
Design/methodology/approach: After COVID-19 instability has prevailed in many areas of human activities and societies, as well as in businesses and economies. The strongly popularised, for more than a decade, the concept of Industry 4.0 was transformed. In the new reality more important there were socio-economic and environmental problems. In the new concept called Industry 5.0 three aspects are important: human factors, resilience and sustainability. The above-mentioned aspects were included by the European Commission in the document: “Industry 5.0. Towards a sustainable, human-centric and resilient European Industry”. The document was published in January 2021. The idea of Industry 5.0 refers to the concept of Society 5.0 in the labile environment after the COVID-19.
The paper was realized based on the SLR method. The author used the bibliometrics of scientific publications about Industry 5.0 available in the scientific database Scopus.
Findings: This paper presents the policy assumptions of Industry 5.0 based on studies from the political documents and scientific papers. The first scientific publications on Industry 5.0 were registered in scientific databases in 2016.
Originality/value The presented frameworks of the Industry 5.0 based on literature review complemented (expanded) the understanding of the European development policy presented in the document: Industry 5.0. Towards a sustainable, human-centric and resilient European industry (European Commission, Brussels, Manuscript completed in January 2021).

Keywords: Industry 5.0, human factors, resilience, sustainability, environmental volatility.

Category of the paper: literature review/general review.

1. Introduction

Since 2020 up to now in many socio-economic areas a deep revision of development directions (principals) has been made. The changes were conditioned by the need to effectively confront the threat of SARS-CoV-2. The first cases of human infection with the virus were reported in late 2019 in the city of Wuhan in eastern China (Zhu et al., 2020). The world of politics, science and practice, with up-to-date knowledge and technologies, took action to safeguard the daily lives of people and the functions of societies, and set about tackling the causes of stunted economies, industries and business (Zaho, 2020). During the pandemic, radical restrictions were required in many areas of social life and economic activity in order to protect the lives and health of citizens in the first place, often at the expense of citizens' rights (civil liberties) and limiting the autonomy of business. In Poland, the beginning of radical restrictions began in March 2020. The final regulation of restrictions took place in the Document of the Council of Ministers of 26 November 2020 on the establishment of certain restrictions, orders and bans in connection with the occurrence of an epidemic state (Dz.U. 2020, poz. 2091). For many constraints, a large number of companies were on the verge of real bankruptcy, due to interruption of supply chains or lack of customers, among other reasons (OECD report, 2020). Currently, governments around the world have serious post-pandemic problems (energy crisis, high levels of inflation, falling real incomes, post-pandemic health problems and others). At various levels of government, policy agendas have begun to be revised and updated. The difficult situation in many levels of human activity after COVID-19, is named the post-pandemic crisis. The emergence of a pandemic on a global scale was the situation for which the world was not prepared. The pandemic was the 'black swan' of the modern world (Taleb, 2020).

After the pandemic, the notion of 'resilience' became increasingly important, not only in relation to the health status of societies, but also in relation to economies, industries and businesses (Silva et al., 2020). Professionals and scientists from a variety of backgrounds proceeded to revise the goals and assumptions made in previous plans, programmes, strategies and models (Verma, Gustafsson, 2020). According to M. Glenszczyk (2022), organisations have introduced into their value attributes, building stability by making business immune to economic, social, health shocks and any other 'black swan' event that could surprise business and show its helplessness.

The conception of resilience was noted by the European Commission (EC) in the document "Industry 5.0. Towards a sustainable, human-centric and resilient European Industry" published in January 2021. In the document, the European Commission, centrally placed human factor, sustainability and resilience of business in the labile environment. The Industry 5.0 is a new model of development after the COVID-19. Besides of the EC document, the term Industry 5.0 is used in scientific and popular publications. The first scientific paper about Industry 5.0 was published in 2016. In 2017, the term 'Industry 5.0' appeared in studies on LinkedIn. Presented concept was about the return of the human touch to industry, by the collaboration between humans and intelligent technologies (Piątek, 2018). The most scientific publications about the Industry 5.0 concept in scientific databases were in 2022. The author of this study analysed publications registered in the Scopus database. The author of the paper used a systematic literature review. In the study the literature review is treated as an appropriate research method (Czakon, 2011). Papers about Industry 5.0 were analyses. Results of the literature review extended the findings taken from the European Commission's formal document on Industry 5.0.

The analysis performed made it possible to:

- diagnosing the potential for interest in the concept of Industry 5.0 in the area of science in the period from 2016, when the first publication on Industry 5.0 in topic was registered in the Scopus database, to the end of 2022,
- identifying and defining three areas of Industry 5.0 perceptions, in line with EC policy, and described by the adjectives: sustainable, human-centric, resilient,
- presenting a generic division of research areas within the Industry 5.0 concept, ordered according to orientation towards sustainability, placing the human being at the centre of technological transformations and ensuring stability by using the functions of the developed technologies of the fourth revolution,
- looking for differences and similarities between Industry 4.0 and Industry 5.0.

The study was performed in order to better understand the concept of Industry 5.0. The paper consists of three main parts (sections). Section 1 presents the results of the bibliometric analysis performed for the keyword: [Industry 5.0] included in the title of scientific publications registered in the Scopus database. Section 2 is divided according to the European Commission's directions for Industry 5.0. The focus was on the typology of research areas during the labile environment (from the outbreak of the COVID-19 pandemic to the present). The final section (Section 3) is a summary of the similarities and differences between Industry, 4.0 and Industry 5.0. The paper concludes with a synthesis of the final conclusions about the Industry 5.0.

2. Bibliometrics of scientific papers about Industry 5.0

The first publication that had Industry 5.0 in its title was registered in the Scopus database in 2016. It was the publication by Sachsenmeier, P., which dealt with bionics and synthetic biology, in terms of the structure and operating principles of organisms and their adaptation in technology and device construction (following the example of living organisms). The processes controlling the actions of organisms are used in automation, computer science, electronics, mechanics and construction (biomimetics). The second area concerned synthetic biology, which has the potential to solve many human problems, from climate disaster prevention to medical breakthroughs. Both areas of research, the author placed in Industry 5.0. (Sachsenmeier, 2016). In 2017, no publication was registered in the Scopus database with Industry 5.0 in its title. The following year, 2018, 3 publications were registered in the Scopus database. The first one with the telling title: Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "the Internet of Things" and Next-Generation Technology Policy, by authors: Özdemir, Hekim was recognised as the beginning of building scientific knowledge about Industry 5.0. The publication, in December 2022, had 179 citations. The second is a book by the author Salgues, B. entitled: Society 5.0: Industry of the future, technologies, methods and tools (275 pages). The third about nuclear energy (Energy 5.0) written by authors Wang, F.Y., Sun, Q., Jiang, G.J., (...), Dong, X.S., Wang, L. In the following years, the number of publications in the Scopus database increased. There were 11 scientific papers registered in 2019, 15 publications in 2020, 51 in 2021 and 126 publications in 2022. In the period called labile, i.e. from the outbreak of the COVID-19 pandemic to the present, the total number of publications about Industry 5.0 was 203. Figure 1 shows the dynamics of scientific publications about Industry 5.0 searched in the Scopus database for the keyword [Industry 5.0] used in the titles of papers.

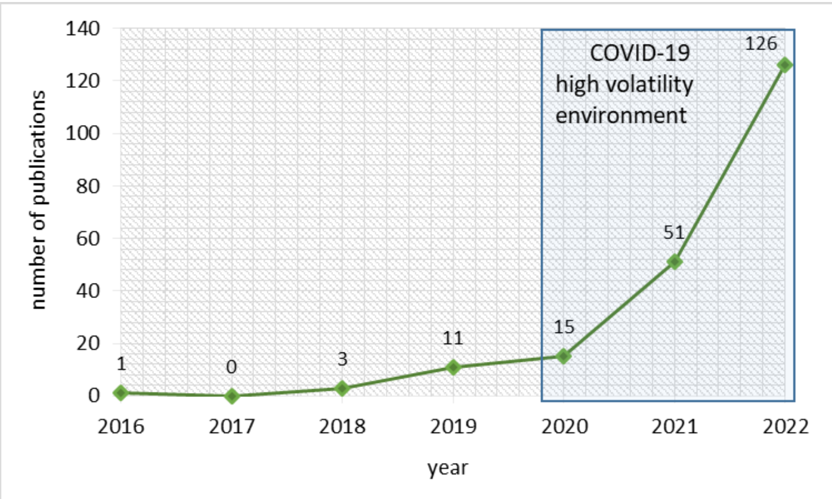

Figure 1. Publication dynamics of Industry 5.0.

Source: Data from the Scopus database.

Considering the subject area of the papers, engineering and computer science were in the lead with more than 100 indications (Figure 2). In Figure 2, topics that received a minimum of 10 indications are included.

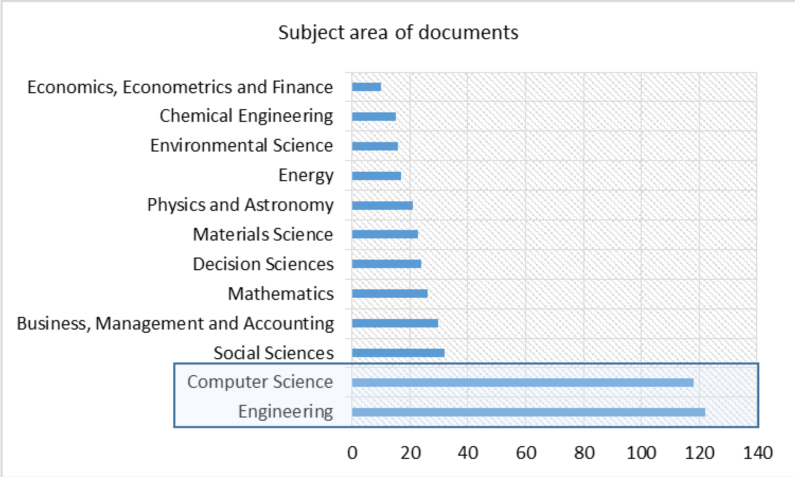

Figure 2. Subject areas of Industry 5.0.

Source: Data from the Scopus database.

The top countries from where the authors of the publications came from were India and China (Figure 3), countries that in many areas of industry (especially traditional industry) are at the top of the world rankings of producers, as well as countries where a significant proportion of the world's population resides. China and India, were countries where the COVID-19 pandemic emerged earlier than in European countries.

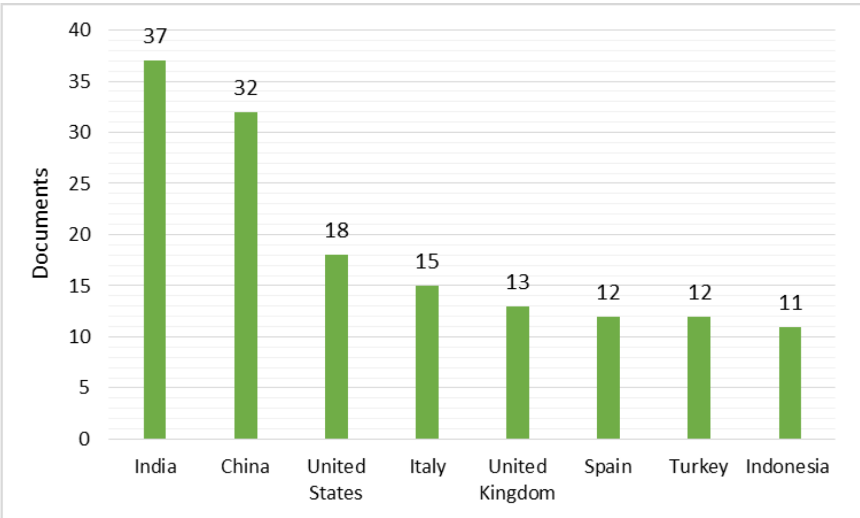

Figure 3. Countries where authors of publications on Industry 5.0 come from.

Source: Data from the Scopus database.

Ordering the keywords used in the publications, apart from the base key, which was Industry 5.0, the authors of the publications also used the key word: Industry 4.0. The transition to the topic of the concept of Industry 5.0, in many publications, was preceded by a reference to the pillars of Industry 4.0 and its history, which started in Germany with the provisions in the High Technology Strategy in 2011. The pillars of Industry 4.0 are artificial intelligence, augmented and virtual reality, IoT, Big Data, the cloud, incremental manufacturing, vertical and horizontal integration of systems and processes, computer simulation and the digital twin. The listed pillars appeared in the concept of Industry 4.0, at different times, e.g. digital twin as late as 2014

(Whitepaper: 'Digital Twin: Manufacturing Excellence through Virtual Factory Replication, by M. Grieves). The technologies mentioned (pillars of Industry 4.0) are achievements of the Fourth Industrial Revolution. Among the keywords used to describe Industry 5.0, in addition to AI and IoT, the key technologies of Industry 4.0, which can be considered as differentiators for Industry 4.0 technology directions, there are also areas typical of Industry 5.0 as descriptors (identifiers), and these are: Society 5.0, sustainable development, blockchain, sustainability of business and human-centric (human at the centre of technological changes).

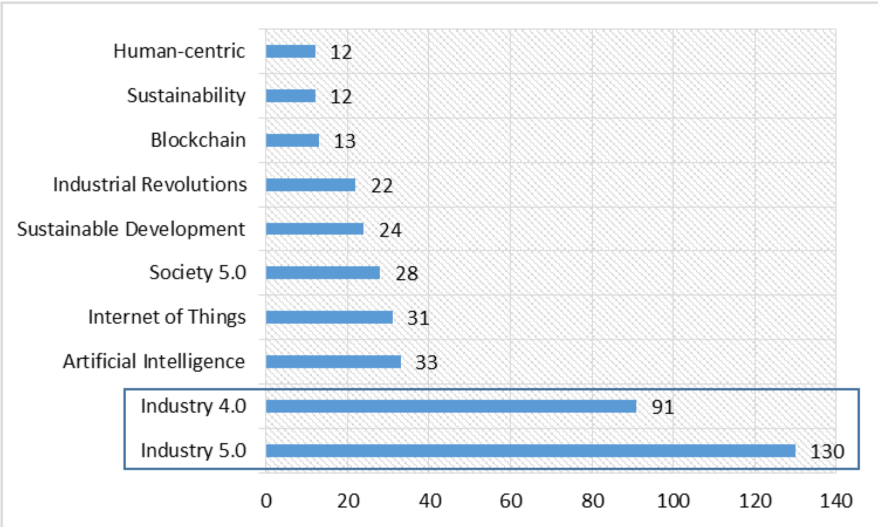

Figure 4. Keywords used in documents about Industry 5.0.

Source: Data from the Scopus database.

Concluding the overall bibliometric review, the publications with the highest number of citations were presented in Table1.

Table 1.
Publications about Industry 5.0 with the highest number of citations (top 10)

Place	Subject	Author/authors	Year	Source	Citation
1.	Industry 5.0-a human-centric solution	Nahavandi, S.	2019	Sustainability (Switzerland) 11(16), 4371	244
2.	Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "the Internet of Things" and Next-Generation Technology Policy	Özdemir,V., Hekim, N.	2018	OMICS A Journal of Integrative Biology 22(1), pp. 65-76	172
3.	Industry 5.0: A survey on enabling technologies and potential applications	Maddikunta, P.K.R., Pham, Q.-V., B, P., (...), Ruby, R., Liyanage, M.	2022	Journal of Industrial Information Integration 26, 100257	147
4.	Industry 5.0 and Human-Robot Co-working	Demir, K.A., Döven, G., Sezen, B.	2019	Procedia Computer Science 158, pp. 688-695	137
5.	Industry 4.0 and Industry 5.0-Inception, conception and perception	Xu, X., Lu, Y., Vogel-Heuser, B., Wang, L.	2021	Journal of Manufacturing Systems 61, pp. 530-535	124

Cont. table 1.

6.	Value-oriented and ethical technology engineering in industry 5.0: A human-centric perspective for the design of the factory of the future	Longo, F., Padovano, A., Umbrello, S.	2020	Applied Sciences (Switzerland) 10(12),4182, pp. 1-25	85
7.	Industry 5.0: Potential applications in covid-19	Javaid, M., Haleem, A., Singh, R.P., (...), Raina, A., Suman, R.	2020	Journal of Industrial Integration and Management 5(4), pp. 507-530	59
8/9	Critical components of industry 5.0 towards a successful adoption in the field of manufacturing	Javaid, M., Haleem, A.	2020	Journal of Industrial Integration and Management 5(3), pp. 327-348	52
8/9	Innovation in the era of IoT and industry 5.0: Absolute innovation management (AIM) framework	Aslam, F., Aimin, W., Li, M., Rehman, K.U.	2020	Information (Switzerland) 11(2), 124	52
10/11	Society 5.0: Industry of the future, technologies, methods and tools (book)	Salgues, B.	2018	*Society 5.0: Industry of the Future, Technologies, Methods and Tools* 1, pp. 1-275	47
10/11	Industry 5.0-The Relevance and Implications of Bionics and Synthetic Biology	Sachsenmeier, P.	2016	Engineering 2(2), pp. 225-229	47

Source: Scopus database.

The paper by the author Nahavandi, S. had the highest number of citation (244 citations).The paper was about the centrality of humans in Industry 5.0. The publication was published in 2019 (at the end of 2019 the COVID-19 pandemic broke out). The documents with the highest number of citations were published in the period 2016-2022.

3. Conception and frameworks of Industry 5.0

Between 2 and 9 July 2020, the concept of Industry 5.0 was the subject of a discussion organised by the Directorate 'Prosperity' of DG Research and Innovation EC. Research and technology organisations participated in the discussion. In its final document of January 2021, the European Commission set out the assumptions for a renewed European industry towards 'Industry 5.0'. In the document key directions of change are sustainable industry, resilient industry and supply chain and human centricity to technology. Smart technologies with the cognitive skills and critical thinking of humans are expected to ensure the success of Industry 5.0 (EC Document, January 2021) Based on an analysis of the European Commission's document, the key determinants of Industry 5.0 are presented in Table 2.

Table 2.
Key directions of Industry 5.0

Area	Direction	Examples
Ecology	• Sustainable: ▪ industry ▪ technologies ▪ production ▪ consumption	• development of production systems based on renewable energy sources, • reduction carbon emissions of 55% by 2030. • reduction of negative environmental impacts: ▪ reuse and recycling of natural resources, ▪ closed loop economy, ▪ waste reduction, ▪ substitution of natural resources by others, • improve processes: new materials, reduce material losses, new technologies • sharing economy: not wasting purchased products, using reusable products, purchasing remanufactured products, handing over (renting, sharing) products to other users • analysis of the product life cycle (from project through manufacture and use to recycling)
Human factor	▪ Human-centric	• people at the centre of the production process - the message: instead of asking what we can do with modern technology, we should consider what technology can do for us - machines and people can work together in harmony, complementing each other, • the use of technology must not infringe on workers' fundamental rights, such as the right to privacy, autonomy and human dignity, • better working conditions and higher safety at work (intelligent robots do dangerous work) • development of the skills needed to operate and cooperate with new technologies (digital competences: basic and advanced with soft skills (creativity, openness, flexibility), • H-CPS: human cyber-physical systems (human-technology cooperation).
volatility environment	▪ Resilient	• industry should be resilient to a variety of geopolitical turbulence and natural disasters as well as other unforeseen events, using the latest technological developments (predictive analytics can forecast upcoming problems and strengthen industry resilience, e.g. weather predictive analytics, maintenance predictive), • supply chains should be resilient to a variety of geopolitical turbulence and natural disasters, the latest technology should be used for this, e.g. maintenance predictive, predictive analytics for demand fluctuations, digital twins.

Source: own elaboration based on the document: Industry 5.0 Towards a sustainable, human centric and resilient European industry, European Commission, Brussels, Manuscript completed in January 2021.

The European Commission distinguishes six basic categories of technological solutions relevant to Industry 5.0:

1) Human-machine interaction.
2) Bio-inspired devices and smart materials.
3) Digital twins and simulation.
4) Transmission, storage and analysis.
5) Artificial intelligence (AI).
6) Energy efficiency, renewables, energy storage and independence from external supplies.

These are key solutions to help achieve the objectives of Industry 5.0, which are sustainability, human centricity to technology, resilience of industry and supply chains to a variety of local and supra-local events. Underpinning the development of the new concept are social and environmental needs. An expert team comprising members of the Faculty of Economics at Westfälische Wilhelms-Universität (WWU) Münster and Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen in Germany addressed this issue in a practical commentary on the European Commission report.

3.1. Sustainability in Industry 5.0

In the modern world, industry cannot survive without sustainability. Sustainability was and is a business paradigm. Sustainability is still a key business strategy, although it was less prominent in the concept of Industry 4.0. The concept of Industry 4.0 was (and still is) built primarily on advanced technologies that take over many of the activities performed by employees. What is important in the Industry 5.0 concept are the ways in which high technology can be used to solve societal problems and radicalise environmental actions.

According to the European Commission, the current development of Industry 4.0 is increasingly moving away from the original assumptions of social equality and sustainability and more towards digitalisation and artificial intelligence (AI) to increase the efficiency and flexibility of production. In the new European Union (EU) policy, the economic impact of the new technologies of the fourth industrial revolution on industrial development is not questioned. The environmental and social impact aspects of the technologies are more strongly exposed. Support is given to solutions in which the new technology contributes to a significant reduction in the consumption of natural resources, the introduction of new input materials into production, the reduction of energy intensity of technology (especially in industries that are energy intensive, e.g. the chemical industry, the steel industry), the decarbonisation of technology (reduction of carbon dioxide emissions), the reduction of energy obtained from coal (black energy) in favour of renewable energy (Green Energy).

Industry 5.0 is about greater energy efficiency and lower carbon intensity. With the world (especially EU countries) experiencing an energy crisis, manifested by high energy prices and energy shortages, an approach aimed at reducing energy intensity is very timely. Despite the energy crisis, EU policy is not changing course. More regulations are constantly being added to existing ones. The Fit for 55 package announced in 2021 aims to accelerate the decarbonisation of industry. Many industrial sectors use too much 'black energy' and much less 'green energy'. In order to achieve a decrease in energy consumption in industrial production, the EU is introducing ever more far-reaching regulations that industry considers harsh. These laws are mandatory. The aim in the 'Green Deal' is to make industry more environmentally friendly and to achieve carbon neutrality by 2050 at the latest.

A priority for Industry 5.0 is also to find solutions for resource consumption, primarily the development of a circular economy by increasing the quality and percentage of secondary raw materials (recycled goods). Optimising the recycling cycle starts with material and product design. The life cycle of products is tracked by IT-computer-based Product Life Cycle Management (PLM Product Life Cycle Management) systems. The new generation of PLM systems makes the entire product life cycle visible (RFID tags, QR codes). Forward and backward information can be viewed throughout the product life cycle. The systems analyse the various stages of a product's life cycle, support users in making appropriate decisions, especially decisions related to product development (Kiritsis, 2010; Kiritsis, 2009; Duda, Olszek, 2021). In Industry 4.0, the emphasis is on the castomisation of the product and the participation of customer in its design. In Industry 5.0, this direction is still being pursued only that first, using at least the digital twin of the product and the digital twin of the process, (recycling efficiency must be traced). Technologies from the extended enterprise must enter supply chains as advanced chains throughout the product life cycle.

The issue of using smart technologies supported by the Internet of Things to improve the environmental performance of industry is a very broad topic. The problem of sustainability in Industry 5.0 is described by many academics and practitioners in addition to the policy community. Kasinathan P. et al. (2022) looked at how sustainability goals can be linked to technological opportunities in the development of Industry 5.0, Society 5.0 and smart cities and towns. The development of Industry 5.0 is equated with Society 5.0.

A number of published authors, including: Zengin et al. (2021), Salimova et al. (2019), link the concept of Industry 5.0 to Society 5.0. Society 5.0 is called an intelligent society because it uses information and computer technology to collect data, transfer information and build knowledge. Cyberspace facilitates society to update and share knowledge. New social and business chains are created in cyberspace. Society 5.0, compared to Society 4.0, which is referred to as the information society, has a greater capacity to integrate the real and digital (virtual) worlds. The strong connection between these two worlds is used for human development as well as for solving social and economic problems within cities and regions, in energy management, healthcare, agriculture and as well as logistics and services (Carayannis et al., 2021). Qahtan, S. and his team (2022) present the transport modelling. Sharma, R. and Arya, R. (2022) discuss the application of environmental monitoring system in smart cities with smart infrastructure. Authors who have undertaken to describe Industry 5.0 indicate and/or explore various areas of equivalence, e.g. human-machine, human-competence (Mazur, Walczyna, 2022; Johri et al., 2021; Margherita, Braccini, 2021).

There is no one-size-fits-all pathway for building sustainability in Industry 5.0. Each area of change may have a distinct pathway (roadmap) for building sustainable value (Ghobakhloo et al., 2022). Value in terms of sustainability can be understood as the concept of looking at the factors that support sustainability from a social, economic and technical perspective. Social, economic and environmental conditions strongly influence the development of Industry 4.0

(Gajdzik et. al., 2021). The process of building sustainable value is continuous. In Industry 5.0, smart industry is being created, a process that was initiated by the concept of Industry 4.0 (Majernik et al., 2021) but, under conditions of a labile environment and strong environmental legislative restrictions, is acquiring characteristics that are described as "Green", e.g. "Green IoT", pointing in favour of using technology to build new aspects of sustainability, e.g. smart circular economy (Fraga-Lamas et al., 2021). The transformation process undertaken requires the refinement or even development of many regulations (Szpringer, 2021), e.g. for data management in blockchain (Leng et al., 2022), product lifecycle monitoring, taming AI (Mubarak, 2022), or securing privacy in blockchain (Singh et al., 2023).

In summary, the direction of building sustainability as a factor supporting technological progress should be considered hypothetical. Sustainability, despite being implemented in Industry 4.0, has been recognised in Industry 5.0 as a determinant (imperative) for building a smart environment.

3.2. Resilience in Industry 5.0

After the outbreak of the COVID-19 pandemic, the European Commission pointed out that the industry was vulnerable to various geopolitical upheavals and natural disasters and therefore introduced the principle of stability (resilient) (EC Document, Jan. 2021). In the last two decades of this century, the effects of a global crisis became apparent twice. The first time, in 2008, when there was a destabilisation of the real estate market in the United States, and the second, after the COVID-19 pandemic in 2020 and its associated consequences, e.g., the energy crisis that became apparent in 2022. The effect of the restrictions imposed, during the COVID-19 pandemic, on the world was to disrupt supply chains. The COVID-19 pandemic made companies (manufacturers) realise how vulnerable (not resilient) global supply chains are to disruption. In response, the European Commission created the 'Recovery and Resilience Instrument'. It serves to support EU Member States to reform and invest in green, digital and socially responsible solutions (Heredi-Szabo, 2022).

In Industry 5.0, activities that strengthen the resilience of supply chains against possible threats and crises are supported, as was the case with the coronavirus pandemic. The topic of technological improvement of blockchain is addressed in both the concept of Industry 4.0 and Industry 5.0. It is sometimes difficult to insert a boundary between activities related to the application of Industry 4.0 and Industry 5.0 or other technological solutions to the creation of blockchain, hence the entries in publications of the form 'Industry 4.0/5.0' (Kaur et al., 2022; Dhiman, Nagar, 2022). Industries have many tools at their disposal to respond to and even anticipate disruptions. Using Big Data and advanced data analysis methods, potential risks can be assessed in real time. Additionally, predictive maintenance in smart factories also supports the maintenance of supply chains. Blockchain technologies strongly linked to the Internet of Things are referred to as BCoT (Blockchain of Things) (Karmakar et al., 2022). Supply chains using smart technologies, are able to 'build resilience' already belonging to a new generation of chains and are part of Industry 5.0 (Sriman et al., 2022). In these solutions, the blockchain user is placed at the centre (user-centric blockchain) (Yank et al., 2022).

3.3. Human-factor in Industry 5.0

The next important direction of Industry 5.0 is the human-centricity of technology. Prior to the European Commission document (Jan. 2021), which used the phrase 'human-centric', this statement had already appeared in studies by Romero et al. (2015), who used the term: human-automation symbiosis. In the following year (2016), Romero, et al. introduced "Operator 4.0" in "A Human-Centric Perspective on the Fourth Industrial Revolution Technologies".

In the Fourth Industrial Revolution, during the automation of production processes, even before the initiation of the concept of Industry 4.0, attention was paid to the integration of humans with automation (Sheridan, Parasuraman, 2006; Tzafestas, 2006; Lorentz et al., 2015). The cited authors emphasised that increasing automation cannot remove humans completely from workplaces.

The strongly popularised concept of Industry 4.0 called for more attention to the relationship: man and machine. Lorenz et al. (2015) asked: How will technological transformation change the industrial work environment by 2025? As technology advances, the view of the role of humans in production processes is changing. The introduction of new technologies must go hand-in-hand with a discussion of the importance and need for human labour (Daugherty, and Wilson, 2018). While each industrial revolution recognises the power of technology for the development of industry, the achievement of business goals must interact with the development of employees to preserve the human-machine relationship.

In a cyber-physical space, people operate and supervise technologies, teach machines to be intelligent, track processes through real-time data provided from machines and increasingly interact with machines. In the cyber-physical space being built, it should remember the basic principle that technologies that replace human labour must be combined with the capabilities of the people who introduced them (Romero et al., 2015). Industry 4.0 is the combination of key technologies, information and computer systems, processes with their visualisation, intelligent products as well as the competences of people into a single network that oversees itself increasing the efficiency of work execution. At the heart of factories are Cyber-Physical Production Systems (CPPS) (Lee et al., 2015; Lee, 2015; Liu et al., 2017). When a human is introduced into this system one gets an H-CPS (Human Cyber-Physical System) (Flores et al., 2020; Romero, 2016).

Technologies, referred to as enabling (Ruppert et al., 2018), require the involvement of fourth-generation operators: "Operator 4.0". Operator 4.0, due to the breadth of technological solutions employed, can be a device teacher, solution mentor, process controller, robot assistant, machine learning developer, manager for mobile robots, cyber-physical systems analyst, machine-to-machine liaison, artificial intelligence operator, design engineer, wireless computer network operator, computer application operator, etc. (Rupper et al., 2018). This multiplicity of tasks is a result of and primarily due to the types of communication and communication technologies and systems (Ruppert, et. al., 2018; Romero, and Stahre et al., 2016; Romero et al., 2016). Ruppert et al. (2018), influenced by the study by Romero, et al. (2016), performed an analysis of the interaction of technologies and operators, identifying eight types of 'operators' that could play an important role in industrial production in the Fourth Industrial Revolution (Table 3).

Table 3.
Operator types in the Fourth Industrial Revolution

Original nomenclature	Simplified profile notation	Description of the operator profile
Super-strength operator	Operator + Exoskeleton = Super-Strength Operator	• The operator with an exoskeleton can increase his physical strength.
Augmented operator	Operator + Augmented Reality = Augmented Operator	• The operator uses augmented reality devices and he can be an augmented reality developer.
Healthy operator	Operator + Wearable Tracker = Healthy Operator	• The operator uses the equipment to monitor his physical condition and measure psycho-sociological parameters.
Virtual operator	Operator + Virtual Reality = Virtual Operator	• The operator uses the virtual world in his work.
Smarter operator	Operator + Intelligent Personal Assistant = Smarter Operator	• The operator works with an intelligent personal assistant (artificial intelligence).
Collaborative operator	Operator + Collaborative Robot = Collaborative Operator	• The operator has a collaborative robot to assist him.
Social operator	Operator + Social Networks = Social Operator	• The work of the operator focuses on social networks. He can be a web designer (webmaster), a web traffic manager, a web architect or a website positioner.
Analytical operator	Operator + Big Data Analytics = Analytical Operator	• The operator is responsible for the analysis of Big Data and can be a computer network analyst.

Adapted from: Ruppert et al., 2018.

In the Fourth Industrial Revolution and the Industry 4.0, the demand for employees with information technology (IT) and computer skills has increased. The new requirements for employees in the fourth industrial revolution are widely discussed among business practitioners and market analysts as well as in political arenas. Ongoing discussions in scientific circles have been the subject of publications by, among others: Botthof, and Hartmann (2015), Becker (2015), Böhle (2017), Windelband (2014). According to the Industry 4.0 nomenclature, an employee working with new technology is called an "Engineer 4.0" (Astor, 2017), and a manager of smart environments is called a "Manager 4.0" (Gracel, Makowiec, 2017). Companies and educational organisations aim to develop the tech-digital competencies and soft skills of current and future employees.

In the fourth industrial revolution, the focus is on a set of technical skills for building a collaborative environment between humans and intelligent machines (I2M). The acronym I2M (Intelligent Integrated Manufacturing) was introduced by a working group at ESTEP as a manufacturing delivery system that characterises the integrated process of monitoring, control and management of machines (definition from the European Commission's Blueprint study of May 2020). The aim of I2M is to optimise production processes and manage resources efficiently by increasing connectivity between sensor networks used at different stages of steel production. Knowledge of process (equipment) control and conversation methods appears to be a basic requirement for future employees. Employees in engineering and technical positions follow (using IT support technologies) manufacturing processes. Among the technical skills needed are operation of IT-computer systems, operation of intelligent technologies, management of networked distributed devices, etc. In addition to technical skills, analytical and conceptual skills as well as statistical knowledge are needed.

Due to the diversity of Fourth Industrial Revolution technologies, organisations are becoming more open to collaboration between IT teams and technologists in the development of computer systems and technology installations. Many decisions rest on small staff teams led by highly qualified engineers. Operator teams are located in control rooms where process operations are coordinated. Leading operator teams are characterised by technological expertise with knowledge of areas such as additive manufacturing, 3D modelling, data analysis, computer programming and machine learning (European Commission Document, EASME, May 2020, pp. 77-78).

In the European Commission's document, the premise of 'technologies that adapt to people' was proposed. Today the premise of Industry 5.0 is needed in a situation where there a shortage of skilled workers. Enterprises must, on the one hand, use technologies that people, even without special skills, can handle and, on the other hand, encourage employees to develop technical and digital competencies. According to the Manual 4.0 study (Inspire Consulting), four stages of change can be distinguished from the employee's perspective in the process of adapting new technologies (quoted from: Manual 4.0 document of Inspire Consulting):

- pre-contemplation phase – The employee is not interested in technological changes. From his perspective they are unnecessary. He does not foresee any benefits from cooperation with intelligent technologies;
- contemplation phase – The employee considers action and declares readiness to cooperate with new technologies, but does not actively participate in the introduction of changes (postpones them);
- preparation phase – The employee shows a real readiness for technological change and takes action, e.g., plans to upgrade qualifications, develops new skills;
- action phase – The employee actively undertakes change-related activities by first learning about new systems, technologies, installations, programmes, applications, algorithms, etc., and then starting to work with the new technologies;

- consolidation phase – The employee has been functioning in the new way for some time, is strongly involved in work, working with intelligent technologies provides him/her with satisfaction, and quickly learns new skills, which come almost spontaneously.

The World Manufacturing Forum (Report…, 2019) prepared a list of the most important skills in the Fourth Industrial Revolution (Table 4).

Table 4.
Skills in the future of manufacturing

Skills	Description
Digital literacy as a holistic skill to interact with, understand, enable, and even develop new digital manufacturing systems, technologies, applications, and tools	The employee • has basic ability to work with digital systems, technologies, applications and tools. • understands information and computer systems, • operates production lines, • uses mobile devices, • understands process visualisation systems, • has manual skills and other psycho-physical qualities, e.g. speed, reflexes, attention span, etc.
Ability to use and design new AI and data analytics solutions while critically interpreting results	Refers to the use of artificial intelligence and data analytics and the critical interpretation of results. The employee has • analytical skills, • statistical knowledge (knows and applies standard quantitative and qualitative analysis tools for forecasting), • conceptual skills. The employee is able to analyse and interpret quantitative and qualitative data.
Creative problem solving in times of abundant data and technological opportunities in smart manufacturing systems	Refers to the use of big data and diverse technologies to find creative solutions. The employee is characterised by • creativity, critical thinking, perceptiveness., communication skills. The employee has • the ability to work in a team, • organisational skills which enable you to • realise design objectives • and undertaking professional activities. The employee is able to • accept and assign tasks in a team, • link cause and effect.
A strong entrepreneurial mind-set including proactiveness and the ability to think outside the box	The employee is entrepreneurial. The employee has • basic knowledge of economic theory and the nature of the determinants and laws of the economic process, • knowledge of economic analysis. The employee knows • enterprise processes, • basic principles of rational management of human, natural and capital resources. • human, natural and capital resources. The employee has • the ability to think and reason rationally.

Cont. table 4.

Ability to work physically and psychologically safely and effectively with new technologies	Refers to coping with new technologies. The employee has • good physical and mental conditions (state of health, speed of reaction, rationality of thinking, etc.).
Inter-cultural and -disciplinary, inclusive, and diversity-oriented mindset to address new challenges arising from a more diverse manufacturing workforce	The employee has • the ability to adapt to technological and process changes (Flexibility Manufacturing), The employee is • flexible, • aware of the dynamics of change in the company and its environment. The employee is characterised by • knowledge compilation. The employee is able to • cooperate with different teams.
Cybersecurity, privacy, and data/information mindfulness to reflect the rapidly increasing digital footprint of the manufacturing value chain	Premise: larger volumes of data mean a larger digital footprint, which needs to be handled responsibly, so you need security systems and staff to handle them. The employee should be • aware of the need to protect the company's data and intellectual property.
Ability to handle increasing complexity of multiple requirements and simultaneous tasks	Premise: There are a variety of demands on employees to perform tasks in smart industry. The employee should • cope with increasingly complex working conditions. The employee should be characterised by • agility, flexibility, adaptability, etc.
Effective communication skills with humans, IT, and AI systems through different platforms and technologies	Necessity: in addition to communication with colleagues, business partners, etc., there is an increasing need to exchange with IT and AI systems on different platforms and using different technologies. The employee is familiar with: • principles of communication platforms and systems. The employee knows how to • interact with information technologies and operate computer and mobile devices, • work with AI
Open-mindedness towards constant change, and transformation skills that constantly question the status quo and initiate knowledge transfer from other domains	Transformation means being open to continuous change, resulting from technological progress and knowledge transfer from other fields. The employee should be characterised by • openness to innovation, • cognitive skills, • knowledge of cause and effect phenomena, • awareness of the interconnectedness of jobs in the production cycle, etc.

Adapted from: “Skills for the future of manufacturing” by The World Manufacturing Forum, 2019.

In a paper on Industry 5.0, published by the European Commission (Jan., 2021), it was pointed out that in reality only four of these skills are digital skills - the others are soft skills, based on creativity, openness and flexibility. The four digital ones include working with information and computer systems and technologies, handling the complexity of manufacturing technologies (technical and technological competences) together with process support information systems, as well as artificial intelligence algorithmic skills (intelligent competences) and analytical skills (Big Data). The competence structure is T-shaped and includes digital, technical and soft skills.

Digital (IT) skills belong to digital competences. The competences[1] can be divided into: basic, extended and advanced. The first group includes competences related to the daily (routine) operation of advanced technologies (automated production lines) together with knowledge of the use of information and computer process support systems. This group also includes the ability to use mobile devices and to use basic computer software. This group of competences is the base for building digital competence of employees. In an IT-dominated world, an employee must be able to use mobile devices and computers as well as operate in internal and external IT networks. Digital competences that are above basic or even advanced include, for example, AI algorithmisation, designing robotic systems, constructing virtual worlds, augmented reality, programming applications, creating data structures, creating interfaces according to user requirements, designing control systems for continuous and discrete control systems using numerical identification and optimisation methods, etc. Digital, or digital, skills need to be continuously transformed due to the rapid development of technology and increasing user requirements. The development of digital competences is supported by openness and flexibility of employees towards technological changes (Gajdzik, Wolniak, 2021; Biały et al., 2019).

In Industry 5.0, the emphasis is on technological support vis-à-vis employees who do not, for the moment, have the right competence. The handling of advanced technologies should be simple and free of human factor errors. This area also seeks to improve occupational safety. EU policy, recognises, justifiably, that industry still has a high accident rate. Human-centred cooperation between humans and machines is expected to contribute to a safer working environment. Robots can perform particularly strenuous and repetitive tasks that involve high physical effort. This has a positive effect on both the health of workers and a reduction in accidents. Work accidents that occur due to excessive physical exertion or health complaints can thus be largely prevented. Sensors detect all disturbing events in the operation of the equipment and inform the operator immediately. The operator does not have to accompany the equipment to its place of operation (he or she does not have to be on the production floor). Monitoring the operation of the equipment is possible from a distance. When a dangerous situation occurs, the machine suspends or slows down operation until the risk is eliminated. Smart cameras are also used to monitor equipment operation. The material collected in this way is sent in real time to a central control room, where the operation of the machines is managed (Gajdzik, 2021; Hancock et al., 2013). Such working conditions can be put: don't do what's dangerous, (the machine will do those things), don't work in conditions that are high risk to your health, (you have an intelligent robot). Changes in working conditions are followed by changes in work ergonomics. There is a need to analyse the relationship: human-technology, in order to parameterise it (Lee, Seppelt, 2012).

[1] Competences consists of skills, knowledge and experiences.

4. Industry 4.0 and Industry 5.0

When comparing Industry 5.0 with the previous concept, Industry 4.0, it is possible to find both common characteristics (similarities) and differentiating features (differences). The range of common features relates primarily to the applied key technologies of the fourth industrial revolution. Unlike previous industrial revolutions, the current transition is no longer accompanied by revolutionary changes. The technologies or pillars of Industry 4.0, such as the Internet of Things, artificial intelligence, Big Data, cloud computing, additive manufacturing processes, augmented reality and virtual world, are also applied in Industry 5.0. Industry 4.0 technologies are available and will continue to play a major role in the development of industries, economies, societies. In addition to the Internet of Things, artificial intelligence or additive manufacturing processes, of decisive importance, for the development of societies and economies, is the 5G network, which has long been part of the ongoing development and the expanded 6G (Dihman et al., 2022).

There is also some correspondence between the objectives of Industry 4.0 and Industry 5.0. Both concepts focus on sustainability and solutions to increase the resilience of supply chains, but in Industry 5.0 there is a greater industry focus on people, social and environmental issues, while in Industry 4.0 there was a greater focus on the development of Fourth Industrial Revolution technologies in symbiosis with the established, (Agenda) goals of industrial and supply chain sustainability.

An important difference between Industry 5.0 and Industry 4.0 is that Industry 4.0 exposes the achievements of the fourth industrial evolution, while Industry 5.0 points to the goals that technology development should provide. Industry 5.0 addresses socio-economic problems and tries to find possible solutions using the technologies of the fourth industrial revolution (Heredi-Szabo, 2022). Industry 5.0 points to key objectives on which the development of industries, societies and economies can - and above all should - be built. Economic and technical goals, e.g., productivity growth, technology intelligence, which were highlighted in Industry 4.0, are encapsulated in the next concept with objectives such as: improving the well-being of workers, protecting the environment and making supply chains more resilient to possible crises.

The Fourth Industrial Revolution and Industry 4.0 focused primarily on the digitalisation of processes and the application of artificial intelligence to improve productivity, and focused less on the role of workers in smart manufacturing or the transformation of supply chains. Industry 4.0 technologies equally impact the economy, the environment and society. Human orientation, sustainability and resilience are becoming increasingly important in Industry 5.0, and the development of digitalisation will be stronger than before. Industry 5.0 is neither a development nor, still less, an alternative to the concept of Industry 4.0. It can be seen as a kind of course correction of the sequence taken by Industry 4.0. There is a preponderance of similarities over differences between Industry 4.0 and Industry 5.0 (Table 5).

Table 5.
Similarities and differences between Industry 4.0 and Industry 5.0

Directions	**Industry 4.0**	**Industry 5.0**
Technology	The technologies of the Fourth Industrial Revolution are the pillars of Industry 4.0: IoT, AI, additive manufacturing, Big Data, computer simulation, digital twin, ICT integration, VR, AR, visualisation.	Fourth technologies are still part of ongoing development but their usefulness for society, humans, ensuring sustainability and stability is emphasised.
Sustainability	Technological development in line with sustainable development of industry.	Highlighting the importance of technological development to achieve radical progress in sustainable development.
Supply chains	Improving supply chains through digitization and technologies of the Fourth Industrial Revolution.	Building the resilience of supply chains using advanced technologies and IoT to economic problems and global crises, as well as other events with global impact.
Human factor	Technology displaces humans, automation of production lines, robotisation of activities.	People at the centricity of technological change, improving working and safety conditions. Technology supports people.
Society	Society 5.0 with smart cities.	Society 5.0 with smart cities and towns.

Adapted from: Przemysł 5.0: Kolejny krok w rozwoju produkcji przemysłowej?, G. Heredi-Szabo, 28 maj 2022 [online] https://knowhow.distrelec.com/pl/internet-rzeczy-iot/przemysl-5-0-kolejny-krok-w-rozwoju-produkcji-przemyslowej/; Przemysł 5.0 - człowiek, technologia, stabilność, 04 kwi. 2022 [online]https://www.mecalux.pl/blog/przemysl-5-00.

Summary

Industry 5.0 can create opportunities for workers and entrepreneurs while helping the environment. Changing the current approach will not only increase production efficiency, but also make more rational use of available natural resources and provide better working conditions. The opportunities from applying technology to achieve significant improvements in productivity as well as in the sustainability of production and products are numerous. It is difficult to cover them all in one place (topic). It seems right that the EU draws attention to the use of innovative solutions to achieve sustainability and react to unpredictable situations such as: global pandemics, environmental and natural disasters. From the impact of the COVID-19 pandemic, the policy community and scientific bodies have drawn many lessons for the future. It is necessary to build the resilience of industries and economies so that they can better react to disruptions of the magnitude of global disasters. The volatile environment with the 'black swan' that was COVID-19 forced the search for new values in existing development. The Industry 5.0 should be human-centric, resilient, sustainable. Therefore Industry 5.0 is the next step in the industrial revolution process.

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