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INDUSTRY 5.0 – A NEW CONCEPT OF INDUSTRIAL DEVELOPMENT

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Improving production is related to the continuous development of digitization, the use of IoT technologies, robots, and automation. Such solutions make factories more modern, working in accordance with computerized procedures. However, these changes may raise concerns about the possibility that, ultimately, humans will be excluded from the business environment. This has resulted in the development of a new concept of industry called Industry 5.0, in which man is treated as an element of the business. The study focused on paradigms for the development of this new industry concept and the role of the human factor. The most important criteria, which determine how industry functions under the new conditions, were identified. The main goal of the study was to indicate the relationships between the Industry 4.0 guidelines and the factors that determine the adaptation of industrial solutions to human needs. Moreover, the study was an analysis of the Industry 5.0 concept, identifying areas that require detailed verification in order to determine the importance of the criteria which specify effective industrial operations. An analysis of the literature identified the basic conditions for the transformation of I4.0 into I5.0. Key criteria determining the effective application of I5.0 were found in the areas of human-centricity, sustainability and resilience. These criteria were linked to the requirements that must be taken into account in order to achieve a symbiosis between humans and technical equipment occurring within I5.0. The analysis was supplemented with the practical aspects of how these requirements may be implemented.

Keywords: Industry 5.0, improving an organization's operations, development of technology and production

1. INTRODUCTION

The need to adapt to the new expectations of stakeholders can be considered a justified direction for industrial development. Ensuring the effectiveness of the

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activities undertaken requires a search for development concepts that take into account current and future conditions. Identifying and describing in detail the scenarios for potential changes seems to be a necessary activity to ensure the effective improvement in the processes performed. It is not sufficient to recreate the existing state and rely on analysis of the current solutions without taking into consideration potential directions of development. Changes are happening despite the fourth industrial revolution, referred to as Industry 4.0. As a consequence, this requires a new look at the existing conditions and emerging opportunities in order to efficiently improve industrial solutions used hitherto.

Based on the information obtained from an analysis of the literature, an attempt was made to diagnose existing relationships and, on this basis, indicate premises for their further improvement. The main aim of the study was to draw attention to the need to determine the circumstances regulating the effective shaping of Industry 5.0. In the study, attention was drawn to:

- the course of action determining the effective implementation of Industry 5.0 principles,
- the results obtained, which are an indicator of the possibility of improving the implementation of Industry 5.0 guidelines,
- the practical applicability of Industry 5.0 guidelines.

The study, therefore, aimed to contribute to an understanding of the conditions for adapting business activities to the guidelines related to the needs of humans (in accordance with their physical, sensory and cognitive capabilities), sustainable development (ensuring the efficient use of resources and reduction in energy consumption) and resilience (enabling organizations to cope with disturbances limiting effective business activities).

2. CHARACTERISTICS OF THE ISSUE. THE ESSENCE OF INDUSTRY 5.0

The new concept, which takes advantage of emerging opportunities and minimizes unnecessary burdens, cannot develop without the participation of a human who is considered to be responsible for the activities implemented. At the same time, it should be ensured that the human as a worker is able to function effectively in the industrial environment, since, additionally, he may be considered an addressee of the manufacturing activities conducted. In this sense, Industry 5.0 complements the existing Industry 4.0 in terms of its orientation towards the worker playing an important role in the production process, without constituting a thorough reconstruction of the existing paradigm (Golovianko et al., 2023; Zizic et al., 2022). It is based on solutions in which machines and people function in symbiosis, acting as collaborators, not competitors (Nahavandi, 2019; Longo et al., 2020), whose cooperation increases the possibility of deriving benefits.



When determining possible and necessary actions which affect how Industry 5.0 functions, the rapid development of new technologies and the use of robotic devices should be taken into account. In recent years, there has been a huge increase in the use of robots in the performance of various tasks. The International Federation of Robotics (IFR) estimates that in 2018, approx. 450,000 new industrial robots were installed. In the United States alone, there was a 20% increase in the number of robotic devices compared to 2017 (*The Essential Guide*, 2022). This can be viewed as moving from the virtual environment back to industrial reality. Unlike Industry 4.0, which pays attention to the highest quantity and mass production, Industry 5.0 values how the worker performs and their creativity, as well as high quality products which are manufactured according to customized orders. The Industry 5.0 concept emphasizes sustainable development considered as the opposite of productivity (Alexa et al., 2022; Golovianko et al., 2023; Nahavandi, 2019). There is a need to achieve effective cooperation between people and technological systems, leading to the attainment of synergistic benefits which result from the use of the best features of each of these elements, i.e. a technical facility and a human operating jointly in a specific environment.

Industry 5.0 can be considered a developmental trend based on the introduction of changes aimed at ensuring human cooperation with technical equipment and preventing waste and losses. The priority of Industry 5.0 is the effective use of the production capacity of machines and the potential of workers functioning in a synergistic environment in which the key feature is the use of emerging opportunities for improvement, thereby increasing the chances of achieving economic success. Industry 5.0 focuses on the skills, knowledge and abilities of workers useful for ensuring effective human cooperation with technical devices, while it also affects the flexibility of production processes and secures the environment of activities performed (Zizic et al., 2022). It is characterized by the integration of advanced technology, such as artificial intelligence, the Internet of Things and large data sets related to the manufacturing technology used, constituting a continuation of the development of existing industrial concepts. Research and innovation are treated as the driving force behind transition to a sustainable, human-centered industry. Industry 5.0 appreciates the importance of using new technologies that ensure prosperity which exceeds the workplace and economic growth. Worker well-being is considered an important element of the manufacturing process and it increases the value of the decisions made.

The concept of Industry 5.0 appeared for the first time in 2017. The term was used by Esben H. Østergaard, CEO at REInvest Robotics. However, the first comprehensive vision of Industry 5.0 was developed in 2021. It was presented in a report by the European Commission entitled “Industry 5.0” (Breque et al., 2021; Dixon-Declève et al., 2022). The concept of Industry 5.0 referred to an improvement in the activities of enterprises, mainly in areas in which the full implementation of the Industry 4.0 concept is impossible, especially due to the conditions of industrial activity, determined by the influence of external factors (Komolka, 2019). These

include, in particular, factors which can be shaped by a production organizer in a limited way.

The basic assumption of Industry 5.0 is the introduction of automation, while at the same time maintaining the possibility of human intervention. Although enterprises aspire to the creation of factories which are almost exclusively automated, it happens that, for factories to run effectively, human participation is necessary.

The problems which condition the effective implementation of the Industry 5.0 concept that have been identified and require solving concern (Breque et al., 2021; Dixson-Declève et al., 2022):

- actions to contend with the issue of an aging population and the resulting limitations,
- widespread overproduction and waste,
- the use of unadapted tools, making it difficult to obtain the intended benefits,
- society's dependence on IT and electricity,
- the general reluctance to introduce changes,
- limited awareness of the need to prevent the generation of waste, in particular waste that can no longer be used.

These are overlapped by the existing disparities in the development of technology, social evolution and changes taking place in society and the business environment. An additional problem is the use of unstructured and unclear process implementation rules in many industries.

The functioning of Industry 5.0 is based on ensuring a balance between technical devices and humans (Kaasinen et al., 2022). The characteristics of industrial development leading to the emergence of Industry 5.0 as a development direction ensuring the fulfillment of human needs are presented in Figure 1.

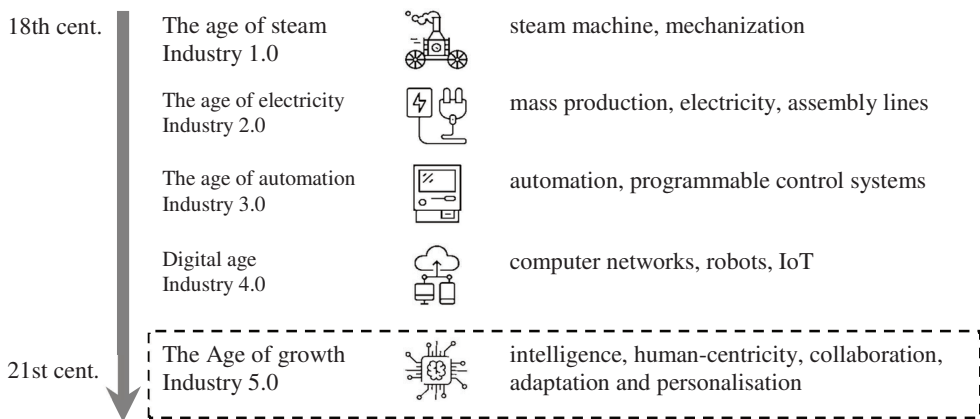


Fig. 1. History of industrial revolutions taking into account development from Industry 1.0 to Industry 5.0 (Hqsoftwarelab.com, 2023)

3. CONDITIONS FOR SHAPING INDUSTRY 5.0

Industry 5.0 is a stage of production development in which machines become sufficiently intelligent to perform complex tasks on their own, using advanced technologies and computing capabilities. On the other hand, obtaining the positive results from the IT solutions applied requires cooperation with people in order to ensure the possibility of the faster and more efficient performance of tasks, meeting needs and expectations. The effect of introducing these solutions is an increase in production efficiency, its more favourable adaptation to needs, often individual ones, and a reduction in the costs of running a business (Nahavandi, 2019; Mad-dikunta et al., 2022).

The effective achievement of the desired state requires that two basic conditions are met, i.e.:

- *Condition 1*: application of solutions consistent with the needs arising from the implementation of Industry 5.0,
- *Condition 2*: application of solutions that increase the effectiveness of the actions undertaken while meeting the first condition.

Identification of the guidelines which comply with these conditions affects the practical performance of activities as part of Industry 5.0.

Condition 1: Characterization and application of solutions which affect the implementation of Industry 5.0

Introducing the automation of production processes has reduced production, quality assurance and logistics costs by as much as 30%. It has also had an impact, through the use of digital supply chain management, predictive maintenance and effective resource management, on the effectiveness of supervision over the manufacturing of industrial products. Therefore, as a consequence of the benefits obtained, it is natural to continue in this direction, which is related to searching for new, better production solutions. An indispensable direction of action is the implementation of solutions in accordance with the Industry 5.0 concept.

The concept of Industry 5.0 is based on three pillars (Zizic et al., 2022; Saniuk et al., 2022):

- human-centricity, which means placing human needs and interests at the centre of the production process and assigning them significant importance in ensuring the effective performance of tasks,
- sustainability, based on the use of a closed cycle of resource use, taking into account ecology, green energy and the consumption of goods, and meeting human needs by ensuring the availability of resources for future generations,
- resilience, referring to the reduction of burdens related to geopolitical changes, as well as crises and challenges resulting from the emergence of threats to the functioning of globalized cooperation.

The implementation of the above activities requires the introduction of solutions thanks to which the use of new technologies will have a significant impact on workers operating in a specific environment, regardless of whether they are considered workers participating in the production process or customers requiring the delivery of an appropriate product (Zizic et al., 2022; Longo et al., 2020). Obtaining effectiveness in the actions undertaken requires an immediate response to changes that occur, which is determined by the availability of appropriate information. The introduction of the human factor into Industry 5.0 thoroughly restructures human tasks in the area of production in a way that benefits all the stakeholders of an organization. The prerequisite for the effective performance of tasks is to ensure that the worker in question is able to indicate their needs and expectations. This requires the ability to transition seamlessly from manual to cognitive work. It is also related to ensuring the possibility of performing tasks with added value in production and working alongside an autonomous workforce, i.e. collaborative robots, which will be perceptual and informed about human intentions (Górný, 2022). The condition for the effectiveness of the solution is the use of a digital description of activities that will increase the efficiency of traditional production procedures.

The characteristics of the factors determining how Industry 5.0 functions in accordance with each of its pillars are presented in Table 1.

Table 1. Characteristics of key issues determining how effectively Industry 5.0 functions

The pillars of Industry 5.0	Characteristics of the actions required, in relation to:		
	the human	the organization	technology
HUMAN-CENTRIC (focusing on humans)	Ensuring effective cooperation between a human and equipment, taking into account human physical, sensory and cognitive capabilities.	Using ergonomic paradigms (physical, cognitive and organizational), allowing adaptation of the working environment to employee needs. Using digitization to improve the quality of the working environment.	Adapting technical solutions to human needs. Ensuring special care for the effectiveness of the interaction between humans and technical equipment.
SUSTAINABLE (sustainable development)	Employing people who can manage change (moving from technology to solutions and from solutions to operations). Organizing workplaces using interdisciplinary knowledge, taking into account the needs and expectations of stakeholders.	Using business models that take into account the impact of actions on achieving sustainable development in environmental, social and economic areas. Using effective support tools (e.g. lean management) to facilitate the introduction of changes.	Ensuring the efficient use of resources and reducing energy consumption. Using waste generated from the processes performed. Conducting data analysis to assess the effectiveness of reducing resource consumption.

cont. tab. 1

The pillars of Industry 5.0	Characteristics of the actions required, in relation to:		
	the human	the organization	technology
RESILIENT (resistance to disturbances)	Recognizing that people are the most important component of processes, because they are the first to detect irregularities and apply effective corrective measures. Recognizing that training and education improving people's skills and influencing the building of awareness and leadership are key factors in increasing resources.	Using existing organizational capabilities, procedures, specific practices and processes. Implementing risk plans and preventive techniques adequate to identified and potential irregularities. Applying a network of production cooperation using a synergy of impact.	Decentralizing the flow network. Ensuring the integration of information connecting different industrial segments as well as levels and processes (through the use of intelligent platforms adequate for the cooperation networks used). Ensuring the availability of data and its protection against unauthorized use.

Source: author's own development based on Zizic et al., 2022.

The application of solutions in accordance with the requirements indicated in Table 1 makes it possible to collect and aggregate data, and consequently ensure the possibility of using advanced simulations and machine learning technology. Systems of this type are a response to the existence of a multi-system application architecture in which data is dispersed in many systems and databases.

Condition 2: Application of solutions that increase the effectiveness of production activities

Industry 5.0 treats employee intelligence as the missing component which increases the effectiveness of its activities. This makes it possible to combine the power of precise and accurate machines with human creativity and ingenuity. The benefits obtained are the result of the use of solutions in accordance with the concept of Industry 5.0 and a derivative of the characteristics of these solutions, and the consequence of better adaptation of the technical environment to human needs. They require the use of solutions that guarantee an appropriate level of organizational maturity. For example (Zizic et al., 2022; Becker et al., 2009; Mettler, 2011):

- ensuring worker awareness of the existence of links between individual paradigms (factors),
- ensuring the durability of existing relationships occurring in each area, e.g. technological and organizational ones,
- reviewing an enterprise's weaknesses, allowing for the identification of key factors enabling the introduction of improvement measures,

- ensuring the ability to adapt efficiently to changes imposed by the external or internal factors affecting how an organization functions,
- rethinking the human-centered approach used in an enterprise and adapting technology and the organization to the needs of workers, and providing them with friendly working conditions,
- introducing solutions to increase the organizational efficiency of an enterprise and indicating the possibility of achieving a balance between various areas of investment activities,
- an ongoing response to changes which requires the consideration of new paradigms of activities.

It is worth noting that the solutions used must be personalized and adequate to the existing needs and expectations of the interested parties, i.e. they must be tailored to the individual participants performing the tasks (Sindhvani et al., 2022). As a consequence, Industry 5.0 technologies require the use of solutions ensuring human and technical cooperation, contributing to an improvement in the efficiency of the activities implemented. Detailed characteristics of the requirements which increase the effectiveness of activities carried out are presented in Table 2. These requirements are based on the characteristics of human relations with technical equipment.

Table 2. Characteristics of the requirements needing consideration in order to obtain a symbiosis between humans and technical equipment within Industry 5.0

Human value	Requirements related to ways of implementing the indicated values
Self-development	Enabling workers to achieve their own goals and attain personal success, and consequently allowing them to demonstrate their skills and competencies in the technical environment.
Responsibility	Ensuring the full transparency of activities and the ability to make decisions based on the identified causes of irregularities.
Credibility	Ensuring the possibility of carrying out tasks in conditions determined by reactions produced over time, using the interpersonal trust found in a hybrid human-machine system.
Welfare	Maintaining an equilibrium characterized by a balanced workload and its sustainable development. Providing conditions that allow workers to achieve physical and mental well-being.
Autonomy	Providing workers with independence of action, freedom, and flexibility at work by allowing autonomous thinking, the ability to make independent choices, and the use of creativity and intelligence.
Altruism	Increasing the importance of teamwork and fostering the well-being of everyone with whom an employee comes into contact during the performance of external tasks.

cont. tab. 2

Human value	Requirements related to ways of implementing the indicated values
Safety	Providing workers with the opportunity to safely perform work, as well as stability and harmony in the physical environment, relations established at work and during the performance of professional duties.
Stimulation	Applying solutions that influence the development of ambitious workers by assigning them a variety of duties requiring continuous learning to ensure professional development.
Sociability	Ensuring good social relations and interactions with co-workers, allowing them to function in a group.
Identity	Taking action to ensure equal rights and integration for all workers, avoiding any discrimination.
Authority	Enabling workers to achieve and/or hold a prestigious position or position of authority and obtain adequate social status, giving them the ability to control other members of an organization and effectively use the available resources.
Conformism	Supporting workers in complying with the applicable rules and meeting their expectations, using social attitudes and loyalty. Limiting the impact of conditions which determine the choice of solutions in accordance with employee needs.

Source: author's own development based on Longo et al., 2020.

The actions taken, in accordance with the conditions indicated in Table 2, affect how effectively an enterprise functions. Therefore, achieving the desired effects requires the use of solutions which determine how workers function after the introduction of solutions congruent with the principles of Industry 5.0, thereby increasing the friendliness of production for the human, the organization and technology.

Obtaining benefits requires the use of solutions that make it possible to:

- improve the business models used and ensure the profitability of solutions which improve the financial result of an organization's operations,
- ensure IT security, increase the operational safety of technical equipment, and reduce the impact of threats to people, thereby improving the efficiency of operations,
- reduce the negative impact of the industry on the environment in which it operates, pursue a sustainable policy of controlled waste generation, and reduce the emission of pollutants into the atmosphere,
- increase the reliability of goods and extend the life cycles of products, consequently leading to a reduction in the use of natural resources,
- facilitate compliance with legal regulations and international production requirements,
- ensure the possibility of optimizing expenditure on providing workers with expected working conditions and ensure an increase in the importance of education, skills and worker involvement.

The need to take into account human needs and expectations in shaping Industry 5.0 requires the adoption of a new approach to improve human-machine communication. The possibilities in this regard are diverse. The development of Industry 5.0 makes it possible to combine the potential with the needs of artificial intelligence and to deepen interaction between people and machines, which is achieved through the use of machine learning. Most often, this means the rapid development of AI, improving data analysis and the communication of workers and devices in all possible configurations. An example of such solutions are collaborative robots (so-called cobots) (Górný, 2022). They require developing simple interactions with people, used both in setting production goals and safety mechanisms. Intelligent technical measures analyze the tasks performed by workers, determine the way they operate and the goals set for them. These activities are analyzed on an ongoing basis in order to identify the possibility of supporting operators in the performance of their assigned tasks.

When identifying the need to introduce modifications that smoothly change the form of work, one should take into account the role of humans in activities that increase the efficiency of Industry 5.0 (Longo et al., 2020; Xu et al., 2021). This requires the use of digital solutions affecting the efficiency of the production procedures used. Automation is treated as a way to strengthen the physical, sensory and cognitive capabilities of humans (Romero et al., 2016). The result is to enable the efficient performance of tasks, generating added value in production and the possibility of functioning alongside an autonomous workforce, i.e. collaborative robots.

4. PRACTICAL ASPECTS OF THE IMPLEMENTATION OF INDUSTRY 5.0 REQUIREMENTS

The effective implementation of solutions compliant with the requirements of Industry 5.0 results in benefits in all of its areas. The solutions applied must strengthen the position of workers while conducting business. This is influenced by the use of technical solutions which cooperate with humans. The replacement of people by technical devices must be rationally justified, for example, by assessing the benefits obtained. Most often, the criterion which determines the solutions used is whether /how they can help people perform their assigned tasks more effectively.

Examples of solutions in line with the Industry 5.0 concept include:

- the so-called “digital twins” – a digital representation of an object functioning in the real world. This solution makes it possible to test machines and optimize system performance without needing to interrupt processes or change reality. All tests and changes are carried out in the simulated conditions of digital reality. Only after their verification do they reach the real environment. These solutions are used in the aerospace, automotive and heavy industries. These are in-

dustries in which it is much easier, cheaper and safer to carry out tests and experiments on online simulations than on real machines or in processes (*Digital Twins...*, 2023; *Racing to streamline...*, 2023).

- transport vehicles moving without the participation of a driver or DTV, able to transport the required components and tools from station to station, independently choosing the most advantageous, optimized itinerary. These include autonomous mobile robots that operate inside production plants. They select objects and transfer them to the required location, moving smoothly around workers and machines. This increases productivity and streamlines processes. By automating the manual movement of materials and improving order picking, they increase the task performance of workers (*Digital Twins...*, 2023; *Racing to streamline...*, 2023).
- the use of so-called augmented reality (AR), which allows a connection of the physical and virtual worlds by overlaying data on a physical object. AR can be used as an activity to support other technologies, such as Digital Twins, or act as an independent tool, for instance to support the maintenance of machines. The use of augmented reality can make it easier for technicians to identify the possibility of correctly performing machine maintenance, carried out in real time (Kloberdanz, 2023).

The effective implementation of the above-mentioned solutions means not only taking into account an enterprise's internal data, but also ensuring an exchange of data with the environment. In practice, this requires selecting that information necessary to ensure consistency in the operation of technical facilities and people in a specific environment (Komolka, 2019). The development of Industry 5.0, resulting from the combination of human and machine, allows for a better use of human mental potential and creativity to increase the efficiency of processes by combining workflows with intelligent systems. Industry 5.0 enables the use of the synergy between humans and autonomous machines, which must be “perceptive” and “informed” about human intentions and desires. This enables the implementation of efficient production processes, allowing an increase in trust in autonomy, and a reduction in both the amount of waste and associated costs.

The development of technologies to ensure adaptation to human needs is aimed at:

- using solutions that reduce network congestion and allow for the exchange of a considerable amount of important data at the same time,
- creating solutions that ensure production monitoring and the prediction of possible scenarios,
- conducting virtual training for workers, allowing them to avoid possibly dangerous situations while learning specific tasks,
- using artificial intelligence, providing the possibility for machines or robots to learn from people and perform tasks based on the knowledge acquired.

Achieving the desired results requires the use of the right approach at the stage of solution implementation. It is reasonable to base the implementation of the Industry 5.0 concept on the use of the 6R principles, which are:

- RECOGNIZE: recognizing the problem,
- RECONSIDER: reconsidering the possibility of applying solutions,
- REALIZE: realizing the solutions selected,
- REDUCE: reducing burdens connected with the use of resources,
- REUSE: reusing whatever is left and can be used again,
- RECYCLE: recycling resources that cannot be used.

The structure of the relationships is shown in Figure 2.

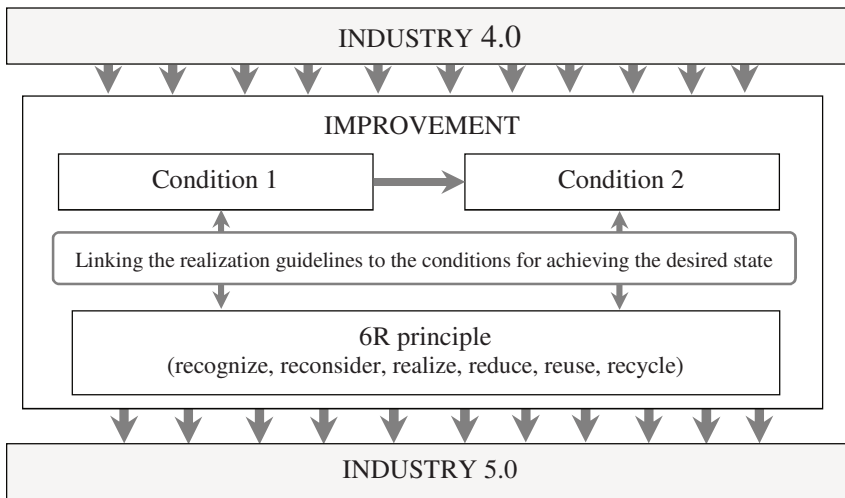


Fig. 2. Characteristics of activities influencing the effective transition from Industry 1.0 to Industry 5.0

Their use makes it possible to:

- optimize the costs of production processes; this is a consequence of reducing energy consumption due to the lack of a need to use lighting, air conditioning, heating and other requirements necessary for workers;
- optimize the workload as a consequence of the rational use of the knowledge and skills of workers according to their qualifications;
- reduce the burden of accidents caused by human error; most often, workers are not involved in the production process at all or perform only control tasks without participating in technical measures that are a source of hazards and burdens;
- improve the tasks carried out as a consequence of the introduction of automation to reduce the scope of activities performed by workers and adjust the intensity of work performed to the capabilities of the cooperating person;
- reduce the number of failures caused by the human factor, which is the result of limited human participation in the completion of tasks and a greater use of technical entities.

Many of the benefits are a direct consequence of a reduction in the number of tasks performed directly by humans. The main benefit is the ability of technical facilities to perform tasks faster, more efficiently and independently through the use of advanced technologies and available computing capabilities. However, in order to achieve the assumed synergistic effect of the application of advanced technology, it is necessary to take into account and implement solutions ensuring large-scale dynamic modelling and the use of digital simulation. This is related to the ongoing monitoring of requirements in the production hall, the virtual training of participants in the tasks to be performed, and the use of intelligent autonomous systems which ensure technological progress in the performance of tasks (Nahavandi, 2019).

The application of solutions in accordance with Industry 5.0 guidelines requires rethinking industrial processes and creating the possibility of applying solutions corresponding to the specific challenges of specific industries. This affects whether the best results possible are achieved in every aspect of the business: the human factor, the organization, and technology. It can be assumed that the fifth industrial revolution will be fully implemented when its three main elements, i.e. intelligent devices, intelligent systems and intelligent automation, will fully connect with the physical world in cooperation with human intelligence. At the same time, the focus of the performance of activities will shift to a systemic approach and the inclusion of social and humanistic issues in technological innovations.

5. SUMMARY

Industry 5.0 is based on three pillars relating to the human, the organization, and technique and technology. It functions by establishing close human relations with technical equipment, providing an opportunity for comprehensive improvement in production. As a consequence, it provides tangible benefits for both parties.

In today's conditions, Industry 5.0 is becoming a global ecosystem shaped by the evolution of existing solutions and adapted to changing needs with an even greater participation of computer techniques. The technologies used aim to achieve well-being in the task realization environment. This requires a change in the rules of production and consideration of restrictions impacting the effectiveness of the activities undertaken.

Despite the benefits obtained, there may be many limitations to be overcome. They include:

- a need to adapt to new conditions by the older part of society,
- a need to eliminate the phenomenon of overproduction resulting from an increase in labour productivity,
- a need to eliminate the lack of skills that may limit the possibility of the effective completion of tasks in a position,

- a need to assign a significant role to ethical behaviour in autonomous systems, including consideration of how autonomous systems can take ethical principles into account.

In the environment of smart factories, monitored by supervisory systems, it is necessary to establish real-time cooperation between technical equipment and humans. This creates a value chain based on cyber communication and cooperation systems, using the Internet of Services, to ensure the efficient performance of tasks.

Nevertheless, the continuous development cannot be treated as a finite state. In the next industrial revolution, people are expected to add high-value tasks to production policy. Standardization and legalization will help prevent major problems between technology, society and business.

Currently, the most important factor limiting the applicability of the Industry 5.0 concept is the required investment. It is difficult to quickly show a return on investment, and it is not easy to obtain financing. Delays in obtaining measurable benefits do not encourage investment (Selvaraj, 2019; *The Essential Guide*, 2022). However, as shown by the experience of Industry 4.0, the indicated direction of development seems to be the right one.

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INDUSTRY 5.0 – NOWA KONCEPCJA ROZWOJU PRZEMYSŁU

Streszczenie

Doskonalenie produkcji związane jest z zachodzącym rozwojem cyfryzacji i wykorzystaniem technologii IoT, robotów i automatyzacji. Zastosowane rozwiązania powodują, że fabryki stają się bardziej nowoczesne i wyrafinowane, pracując według skomputeryzowanych procedur postępowania. Jednakże zachodzące zmiany mogą wzbudzić obawy odno-



szące się do możliwości wyeliminowania człowieka ze środowiska prowadzonej działalności. Spowodowało to rozwój nowej koncepcji funkcjonowania przemysłu określanej jako Przemysł 5.0, w której człowiek traktowany jest jako element prowadzonej działalności. W opracowaniu zwrócono uwagę na paradygmaty rozwoju nowej koncepcji przemysłu oraz rolę w nich czynnika ludzkiego. Wskazano najważniejsze przesłanki wpływające na funkcjonowanie przemysłu w nowych uwarunkowaniach. Podstawowym celem poznawczym opracowania było wskazanie relacji zachodzących pomiędzy wytycznymi Przemysłu 4.0 a czynnikami determinującymi dostosowywanie rozwiązań przemysłowych do potrzeb człowieka. Opracowanie stanowi analizę koncepcji Przemysłu 5.0 wskazującą obszary wymagające przeprowadzenia szczegółowej weryfikacji pozwalającej określić znaczenie kryteriów determinujących skuteczne funkcjonowanie przemysłu. Opierając się na analizach opracowań naukowych, wskazano podstawowe warunki realizacji zmian pozwalających przekształcić Przemysł 4.0 w Przemysł 5.0. Zwrócono uwagę na kluczowe zagadnienia determinujące skuteczne funkcjonowanie Przemysłu 5.0 w obszarach: zorientowanie na człowieka, zrównoważony rozwój, odporność na zakłócenia. Zidentyfikowane wymagania powiązано z wymaganiami koniecznymi do uwzględnienia w celu uzyskania symbiozy człowieka i wyposażenia technicznego zachodzącej w ramach Przemysłu 5.0. Przeprowadzoną analizę uzupełniono o praktyczne aspekty realizacji wymagań.

Słowa kluczowe: Przemysł 5.0, doskonalenia działania organizacji, rozwój technologii i produkcji