Industry 5.0: Generalized Definition, Key Applications, Opportunities and Threats

Attila Kovari

Institute of Digital Technology, Faculty of Informatics, Eszterházy Károly Catholic University, Eszterházy tér 1, 3300 Eger, Hungary kovari.attila@uni-eszterhazy.hu

Kandó Kálmán Faculty of Electrical Engineering, Óbuda University, Bécsi út 96/B, 1034 Budapest, Hungary, kovari.attila@uni-obuda.hu

Department of Natural Sciences, Institute of Engineering, University of Dunaujváros, Táncsics M. u. 1/A, 2400 Dunaujváros, Hungary, kovari@uniduna.hu

GAMF Faculty of Engineering and Computer Science, John von Neumann University, Izsáki u. 10, 6000 Kecskemét, Hungary kovari.attila@nje.hu

Abstract: Collaboration between humans and machines is the main focus of the latest industrial revolution dubbed 'Industry 5.0'. This piece aims to highlight the overall concept, as well as the key applications, opportunities and threats of Industry 5.0. Various definitions of Industry 5.0 are presented, with a focus on the significance of human-robot cooperation and the priority placed on people and eco-friendliness in industrial processes. This article showcases the distinct and inventive customer experiences that Industry 5.0 provides, while also generating value for industrial companies. Additionally, a SWOT analysis delves into the strengths, weaknesses, opportunities and threats brought about by Industry 5.0. Achieving sustainable development goals and gaining a competitive edge are both possible for companies embracing Industry 5.0. Despite the benefits, however, obstacles abound. Issues like integrating human resources into production processes and tackling safety and ethical concerns require attention.

Keywords: Industry 5.0; Industry 4.0; human-machine cooperation; sustainability; SWOT analysis; sustainable development goals; safety issues; ethical issues; human resources

1 Introduction

A series of industrial revolutions have brought major changes in manufacturing and production. The term Industry 4.0 was publicly introduced at the Hannover Fair in 2011 [1], which developed the concept of Cyber-Physical Systems (CPS) into

Cyber-Physical Production Systems (CPPS) [2]. One of the key initiatives of Industry 4.0 is SmartFactory [3]. In the era of Industry 4.0, production systems, in the form of CPPS, can make intelligent decisions through real-time communication and collaboration between "manufacturing things" [4], enabling flexible manufacturing of high-quality personalised products with mass efficiency [5]. In Industry 4.0, the main priority is to automate processes, thereby reducing human intervention in the manufacturing process [6]. Industry 4.0 focuses on improving mass production and performance by digitalisation and AI-driven technologies to increase the efficiency and flexibility of production, but with less focus on social and sustainability principles.

The fifth industrial revolution, Industry 5.0, is an advancement of its predecessor, Industry 4.0, which was centered around automation and digitization. Industry 5.0 is a revolution that recognises industry's ability to achieve social goals alongside growth, putting people at the centre of the production process [6]. Industry 5.0 will place more emphasis on the human factor, customisation, environmental awareness, and the integration of new technologies than previous industrial revolutions. The introduction of Industry 5.0 is based on the fact that Industry 4.0 focuses less on social and sustainability principles and more on increasing the efficiency and flexibility of production [7]. Figure 1 summarizes the industrial revolutions.

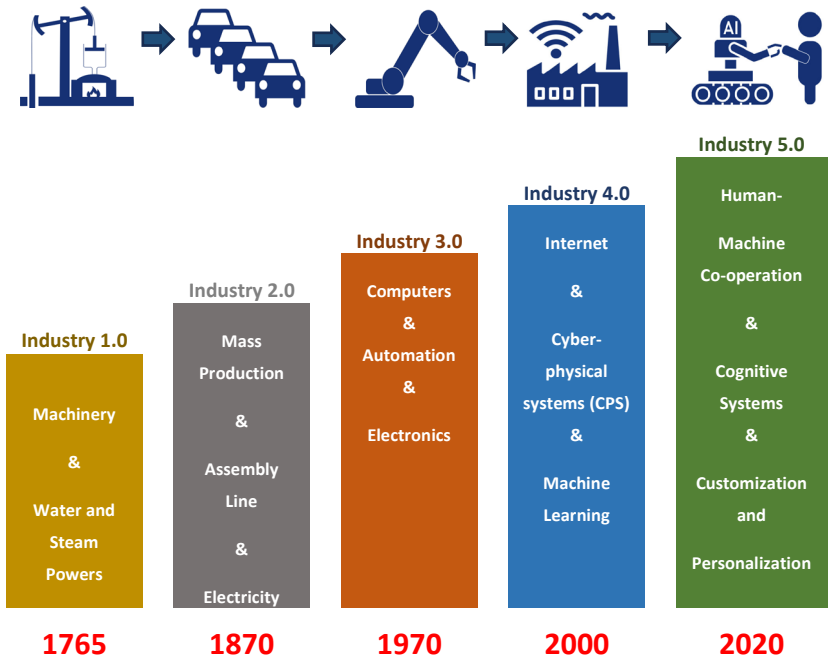

Figure 1
Industrial revolutions

Industry 5.0's focus lies in enhancing the collaboration between humans and machines. Its goal is to improve workplace safety, reduce errors, and boost productivity by optimizing human-machine interaction [8]. The combination of creative human input and smart technology defines the Industry 5.0 model. It allows for workers to not only participate in the production process, but also make important decisions and adapt to shifting circumstances in real-time. Working in conjunction with each other instead of being replaced, Industry 5.0 and Industry 4.0 harmoniously bring forth optimal results for manufacturing and industry. Human-machine collaboration, sustainability and cybersecurity will be key elements of the new industrial revolution.

This paper summarizes the definitions of Industry 5.0 and give a generalized concept for Industry 5.0 applications. Based on a synthesized analysis, it reflects the key applications of Industry 5.0 with the help of a detailed SWOT analysis and highlights the main opportunities and threats of the fifth industrial revolution.

2 Generalized Definition of Industry 5.0

Industry 5.0 is still constantly developing, so experts and researchers from different perspectives have given different definitions for the discussion of this industrial revolution. Since the concept of Industry 5.0 has not yet fully matured, so some general and more specific definitions are summarized below:

- Def1: “The revolution of industry 5.0 means that humans and machines are working together, improving the efficiency of industrial production. Human workers and universal robots are boosting the productivity of the manufacturing industry.” by Amr Adel [9]
- Def2: “Industry 5.0 can be considered the era of the socially intelligent factory, in which cobots converse with people. Enterprise social networks will be used by Social Smart Factory for enabling seamless communication between human and CPPS components. The overall current understanding of Industry 5.0 brings the human touch back to the industry. It also entails the incorporation of AI into human operations to enhance man's capacity. The core of Industry 5.0 is the harmony of machines, humans, values, tasks, and finally, knowledge and skills which results in personalized/individualized products as well as services.” by Leng *et al.* [10].
- Def3: “The Age of Augmentation (Industry 5.0)—will be focused on the cooperation between human intelligence and cognitive computing and on treating automation as a further enhancement of the human’s physical, sensorial, and cognitive capabilities. By putting humans back into the loop, Industry 5.0 profoundly restructures human tasks in the realm of

manufacturing in ways that benefit the workers. They will be upskilled to shift from manual to cognitive labor, to provide value-added tasks in production and to work—with peace of mind—alongside an autonomous workforce, i.e., collaborative robots that will be perceptive and informed about human intention and desire" by Francesco Longo, Antonio Padovano and Steven Umbrello [8].

- Def4: "This approach provides a vison of industry that aims beyond efficiency and productivity as the sole goals, and reinforces the role and the contribution of industry to society. It places the wellbeing of the worker at the centre of the production process and uses new technologies to provide prosperity beyond jobs and growth while respecting the production limits of the planet. It complements the existing "Industry 4.0" approach by specifically putting research and innovation at the service of the transition to a sustainable, human-centric and resilient European industry." by European Commission [11].
- Def5: "INDUSTRY 5.0 is future, but already penetrating trend, of change processes directing towards closer cooperation between man and machine, and systematic prevention of waste and wasting including INDUSTRIAL UPCYCLING. INDUSTRY 5.0 priority is to utilize efficiently workforce of machines and people, in synergy environment. It goes back from virtual environment to real one." by Michael Rada [12].
- Def6: "Bringing back human workers to the factory floors, the Fifth Industrial Revolution will pair human and machine to further utilize human brainpower and creativity to increase process efficiency by combining workflows with intelligent systems. While the main concern in Industry 4.0 is about automation, Industry 5.0 will be a synergy between humans and autonomous machines." by Saeid Nahavandi [13].
- Def7: "In other words, at its heart, Industry 5.0 reflects a shift from a focus on economic value to a focus on societal value, and a shift in focus from welfare to wellbeing." by Jeroen Kraaijenbrink [14].
- Def8: "The 5th Industrial Revolution, which still is emerging, is bent on fostering cooperation between humans, machines, and technology to ensure the stability the workforce and an understanding of worker empowerment." by MOMENTA [15]
- Def9: "The previous tier, Industry 4.0, emerged with the arrival of automation technologies, IoT and the smart factory. Industry 5.0 takes the next step, which involves leveraging the collaboration between increasingly powerful and accurate machinery and the unique creative potential of the human being." by Nexus Integra [16].
- Def10: "The term Industry 5.0 refers to people working alongside robots and smart machines. It's about robots helping humans work better and faster by leveraging advanced technologies like the Internet of Things (IoT) and big

data. It adds a personal human touch to the Industry 4.0 pillars of automation and efficiency." "The pairing of human and machine workers opens the door to countless opportunities in manufacturing. And since the use cases of Industry 5.0 are still in their relative infancy, manufacturers should be actively strategizing ways to integrate human and machine workers in order to maximize the unique benefits that can be reaped as the movement continues to evolve." by James Jardine [17].

- Def11: "The Fifth Industrial Revolution, also known as Industry 5.0, is a new phase of industrialisation, whereby humans work alongside advanced technologies and AI-powered robots to enhance processes within the workplace." by Marina Ruggieri [18].
- Def12: "Industry 5.0, also known as the Fifth Industrial Revolution, is a new and emerging phase of industrialisation that sees humans working alongside advanced technology and A.I.-powered robots to enhance workplace processes. This is coupled with a more human-centric focus as well as increased resilience and an improved focus on sustainability." by TWI [19]

Based on the previous definitions, a synthesized generalized definition for Industry 5.0:

Industry 5.0 focuses on effective human co-work with machines to increase flexibility and sustainability by relying on smart machines.

Industry 5.0 builds on the achievements of Industry 4.0, but rather than replacing humans, it aims to exploit the potential of human intelligence in human-machine interaction more than ever before. This will allow people to use their cognitive abilities and rapid adaptability to improve without sacrificing the accuracy and consistency offered by intelligent machines. In this way, Industry 5.0 focuses on economic, environmental and social impact to make sustainable choices.

Figure 2
Industry 5.0 from the perspective of human-centric sustainability [15]

3 Key Application Areas of Industry 5.0

The following key application areas can be identified for Industry 5.0, the latest industrial revolution that focusing on collaborating with smart technologies to boost production efficiency and improve the workplace environment by combining human creativity with machines. Industry 5.0 has brought a number of innovations and differences compared to previous industrial revolutions, including:

- Human-Machine Collaboration: at the heart of Industry 5.0 is human-machine collaboration. While Industry 4.0 focused on full automation and autonomous systems, Industry 5.0 aims to combine human creativity with machine efficiency.
- Tailored Production: Industry 5.0 will allow manufacturing processes to be customised to individual needs. This means that companies will be able to produce unique products in high volumes without losing efficiency.
- Environmentally conscious: The new industrial revolution places a strong emphasis on sustainability and environmental protection. Companies need to operate not only more efficiently, but also in a more environmentally friendly way.
- Digital Twins and Augmented Reality. These technologies enable virtual modelling and optimisation of production processes.
- Intelligent Systems. This means that systems can anticipate problems and solve them before they become serious problems.
- Cybersecurity. As systems become more complex and interconnected, security risks will increase and companies will need to focus more on cybersecurity.

Putting human creativity and intelligent technology together, Industry 5.0 is the next industrial revolution focusing on man-machine partnership. This revolution aims to amalgam production efficiency and workplace environment. Taking into account these development trends, the following key application areas can be identified with regard to Industry 5.0:

- Collaborative robots (Cobots): These robots work alongside humans on the production line and are able to learn from their human co-workers. Cobots are able to identify and adapt to the activities of their human colleagues, creating a safer and more efficient work environment.
- Cognitive robotics: Cognitive robots are able to learn and adapt to their environment by the intelligent behavior of robots. These robots are able to make decisions independently and collaborate with humans in production processes.

- Digital Twins: Digital twins are virtual copies of physical devices that collect real-time data and perform analytics. These twins help companies to develop and optimize production processes and predict maintenance needs.
- Augmented Reality (AR) and Virtual Reality (VR): AR and VR technologies allow workers to interactively connect with production processes, increasing productivity and efficiency. In addition, these technologies can be used for training and educational purposes.
- Intelligent manufacturing systems: The goal of Industry 5.0 is to create intelligent manufacturing systems that can identify and solve manufacturing problems and achieve maximum efficiency and flexibility by combining human cognitive abilities with machine precision.
- Intelligent healthcare: It can individually monitor the patient's condition and provide personalized treatment with the help of doctors. With the help of cobots, doctors can perform surgeries in cooperation with robots. Routine medical tasks can also be performed by cobots, so doctors can focus on more complex tasks.
- Customized production: Industry 5.0 enables companies to produce customized products according to customer needs by combining the power of humans and smart manufacturing. This includes customizing products and modifying manufacturing processes to customer specifications. It allows companies to produce uniquely customized products instead of mass production. With this method, companies will be able to respond quickly to market changes and customer needs.
- Data-driven decision making: The concept of Industry 5.0 also includes data-based decision making. With the help of smart sensors and IoT devices and humans, companies are able to collect and analyze data to make better decisions about manufacturing processes.
- Education: The combination of smart machines and better trained professionals results in efficient, sustainable and safe production. Industry 5.0 introduces the role of Lead Robotics. This person specializes in machine-operator interaction and has experience in areas such as robotics and AI. Education must reflect this when training future specialists and engineers.

Innovation in Industry 5.0 is bridging human involvement and technology during production. Exciting new applications resulting from technological advancements have the potential to revolutionize the industrial sector. The sparse examples of potential applications shown here are just a taste of the possibilities Industry 5.0 offers.

4 Examination of Opportunities and Threats using SWOT Analysis

The examination of Industry 5.0 opportunities and threats is carried out with the help of a SWOT analysis. For the analysis, it was summarized on the basis of the authors' characterizations related to industrial applications, based on a synthetic overview of many Industry 4.0 and Industry 5.0 papers. The papers used for the analysis can be classified into the following groups:

- general overviews [2], [10], [19], [20]
- industrial and medical applications and research [21], [22], [23], [24]
- management, innovation, economy [25], [26], [27]
- socio and human centric perspectives [6], [8], [9], [28], [29], [30]

Table 1 shows the summarized results of a SWOT analysis based on a synthesis of the literature reviewed.

Table 1
SWOT analysis of Industry 5.0 technologies

SWOT	Content
Strengths	**1. Human and Machine Collaboration**: Emphasizes the interaction between humans and machines, promoting a collaborative environment. Combines human creativity with machine efficiency to enhance productivity and improve workplace safety. **2. Human-Centric Approach**: Puts human needs and interests at the center of the production process. Industry 5.0 prioritizes the well-being of industrial workers, emphasizing their importance in the production process. **3. Customized Production**: Enables tailoring of manufacturing processes to individual needs. **4. Organizational Resilience**: Industry 5.0 focuses on resilience, allowing industries to adapt and thrive in changing conditions. **5. Environmentally Conscious**: Places a strong emphasis on sustainability and environmental protection. **6. Digital Twins and Augmented Reality**: Introduces digital twin and augmented reality technologies into manufacturing processes. **7. Technological Advancements**: The integration of advanced technologies such as IoT, AI, and robotics to create flexible and efficient production systems. **8. Sustainable Manufacturing**: Manufacturing must respect planetary boundaries and be sustainable. The industry meets societal demands while respecting planetary boundaries.
Weaknesses	**1. Complex Technologies**: Introduction and integration of new technologies can pose complex challenges for companies.

	2. Training Requirement: Workers need to acquire new skills for the effective use of new technologies. **3. Social Heterogeneity**: There can be societal differences in values and acceptance. **4. Transition Challenges**: Moving from Industry 4.0 to 5.0 might pose challenges, especially for industries heavily invested in the former. **5. Data Security and Interoperability**: Concerns related to ensuring data security and interoperability between systems. **6. Potential Resistance**: Traditional industries might resist the change due to the costs and complexities involved in the transition. **7. Lack of Clear Definition**: Being a topic in development, there's no precise consensus on its definition, which can lead to confusion and misinterpretation.
Opportunities	**1. Competitive Advantage**: Companies that successfully implement Industry 5.0 technologies can gain a competitive edge in the market. **2. Sustainable Growth**: Environmentally conscious manufacturing processes allow companies to achieve sustainable growth in the long run. **3. Resilience**: Manufacturing must be capable of defending against disruptions and ensuring critical infrastructure during crises. **4. Meeting Societal Demands**: Industry 5.0 offers the chance to realign industries with societal needs, potentially opening new markets and avenues for growth. **5. Innovation and Entrepreneurship**: The emphasis on creating an environment conducive to innovation can lead to the birth of new ideas, products, and services. **6. Strengthening Partnerships**: There's an opportunity to strengthen collaborations between the public and private sectors, leading to shared growth and development. **7. Addressing Global Challenges**: The ability to address significant global challenges such as climate change, rapid consumption of non-renewable resources, environmental pollution, and social injustice.
Threats	**1. Cybersecurity Risks**: As systems become more complex and interconnected, security risks increase. **2. High Initial Investment**: Introduction of Industry 5.0 technologies may require significant initial investment. **3. Productivity Challenges**: Significant investments are needed while also expecting an increase in productivity. **4. Rapid Technological Changes**: The pace of technological advancement might outstrip the industry's ability to adapt, leading to potential inefficiencies. **5. Environmental and Social Challenges**: Issues like climate change, environmental pollution, and social injustice can pose significant challenges to the successful implementation of Industry 5.0.

	6. Potential Overshadowing by Industry 4.0: The existing prominence and momentum of Industry 4.0 might overshadow the newer paradigm, slowing down its adoption. **7. Global Conflicts**: Events like the Russia-Ukraine conflict can elevate complexities in the global industrial context.

5 Insights into Practical Applications and Future Directions of Industry 5.0

At the brink of the new industrial revolution, we witness an amalgamation of cutting-edge technologies and human-centered methods that will bring some significant changes to several industries. Industry 5.0 signifies not only a technological advancement but also a paradigm shift in the operation and growth of businesses. Our scrutiny will explore Industry 5.0's practicability and future prospects, scrutinizing its effect on agriculture, healthcare, and manufacturing while examining future technology progressions, workforce dynamics, and expertise demands. Our investigation targets a comprehensive perception of the opportunities and obstacles Industry 5.0 will present in this impending industrial era.

Industry 5.0 is set to revolutionize various sectors by bringing in more efficient, sustainable, and customized approaches. The future will see advancements in AI, robotics, IoT, and data analytics enhancing human-machine collaboration. This evolution will fundamentally alter the job landscape, necessitating a shift in education and skills development. Embracing these changes is crucial for industries to remain competitive and sustainable in the rapidly evolving technological world.

5.1 Manufacturing

Introducing a paradigm shift in the manufacturing sector, Industry 5.0 is transforming production processes into something more efficient, sustainable, and customized. This envelopment is characterized by the integration of advanced technologies such as AI, robotics, and IoT, allowing machines to support human creativity and decision making rather than just automating tasks. The main focus is to enhance human-machine collaboration, resulting in an agile production line that meets individualized customer needs, reduces waste, and improves resource efficiency. Consequently, this synergy leads to a manufacturing landscape that is more responsive and responsible, in line with the rising demand for sustainability.

5.2 Healthcare

In healthcare, Industry 5.0's potential is transformative. The use of collaborative robots (cobots) and AI in surgeries and patient care marks a significant advancement. Cobots, designed to work alongside human professionals, can assist in complex surgical procedures, offering precision and consistency beyond human capabilities. AI algorithms can process vast amounts of patient data, aiding in diagnosis and personalized treatment plans. These technologies not only enhance the quality of care but also promise to make healthcare more accessible, as they can assist in overcoming human resource constraints in underserved areas.

5.3 Agriculture

In agriculture, Industry 5.0 technologies play a pivotal role in ushering in an era of precision farming. This approach leverages IoT sensors, AI, and big data analytics to make farming practices more informed and precise. From soil moisture sensors guiding irrigation to AI-driven pest control solutions, these technologies enable better resource management, higher crop yields, and reduced environmental impact. Precision farming epitomizes the Industry 5.0 ethos of harmonizing efficiency with sustainability.

5.4 AI and Robotics

Looking ahead, further advancements in AI and robotics promise to deepen human-machine collaboration. Next-generation AI could offer more intuitive and adaptive learning capabilities, aligning closely with human needs and thought processes. Robotics might evolve to be even more flexible and capable of complex, creative tasks, blurring the lines between tasks traditionally thought to be exclusively human or machine domain.

5.5 IoT and Data Analytics

The advancements in IoT and data analytics herald a future where industrial processes are not only more efficient but also more sustainable. Enhanced IoT connectivity will lead to smarter factories, where real-time data analytics can optimize energy use, reduce downtime, and predict maintenance needs. This level of operational intelligence paves the way for industries to not only increase their productivity but also significantly lower their environmental footprint.

6 Discussion

Industry 5.0, this novel concept highlights the significance of prioritizing people and sustainability in industrial processes. More importantly, this new paradigm emphasizes the crucial role of industrial workers in the production process, nurturing collaboration and coordination between human and smart systems. This integration gives rise to the possibility of individualizing products and services on a massive scale, providing unparalleled and innovative customer experiences. Consequently, this creates value and establishes a competitive edge for industrial enterprises. Blending technology with innovative tactics and organizational frameworks is key. The structure, functioning, human resources, and operations of corporations must harmonize with societal demands and stakeholders. To inaugurate a culture of creativity and business, establishing a favorable environment is imperative. Crafting a skilled workforce, investing in R&D, and strengthening public-private sector collaboration must be prioritized. Achievement of sustainable development goals is possible only if industries make themselves resilient, integrate human values with technology and ensure sustainability. Competition and productivity must be weighed against said goals also considering the technological advancements that accompany the new industrial revolution.

People-centeredness and sustainability are the key priorities of Industry 5.0, prompting a paradigm shift in the industrial sector. By placing human needs and interests at the core of the production process, a human-centered approach emphasizes the significance of the human touch over technological advancement. Additionally, this approach brings about fresh roles for industrial workers, as the value perception shifts from viewing them as "costs" to recognizing them as "investments.

In Industry 5.0, the focus is on people and societies, rather than mere technology. To adapt to the diverse needs of industrial workers, the manufacturing industry uses technology that caters to them. The goal is to create a work environment that prioritizes employee well-being, including their physical and mental health. This approach puts emphasis on protecting workers' fundamental rights, such as autonomy, human dignity, and data protection.

For a more balanced work-life and improved career options, industrial employees must constantly train and develop themselves [31] [32]. Additionally, Industry 5.0 prioritizes sustainable manufacturing and encourages industries to be sustainable and respectful of the planet's limitations. One way to achieve this is by creating circular processes that repurpose, recycle and reuse natural resources, ultimately leading to an efficient and sustainable circular economy with less waste and environmental impact.

Industrial production in Industry 5.0 is required to display resilience as a critical strength. This resilience is necessary to combat disruptions and protect crucial

infrastructure. The industry of the future must be agile enough to adapt efficiently to (geo-)political transformations and unforeseen natural emergencies.

The COVID-19 crisis has, in particular, made apparent the fragility of global supply chains and reinforced the necessity for better preparation for the future. Utilizing a host of cutting-edge technologies like the Internet of Things, blockchain, and the latest 6G networks, Industry 5.0 has emerged as a game-changer. By leveraging the power of digital twins, collaborative robots, and edge computing, the entire production process can be monitored and controlled for optimal efficiency and superior quality. Thanks to 3D modeling and simulation, product designs can be perfected and stored digitally before being manufactured on demand, making the storage of large quantities of finished products a thing of the past, and bringing down the costs of inventory management.

Industry 5.0 allows for mass customization, which means that personalized products can be created based on customers' preferences and requirements. This innovation enhances production efficiency and facilitates an interactive and continuous monitoring process between humans and machines. Responsibility for these activities is shared, resulting in increased flexibility.

Identifying alternate routes in the face of disturbances remains paramount in Industry 5.0. Such resiliency can only be achieved with the help of digital tools and methods - think simulations and advanced AI models - that can weigh diverse factors like quality, cost, logistics, and substitution.

The application of Industry 5.0 is not without its share of difficulties and drawbacks. Despite its numerous benefits, one primary issue is social heterogeneity. There exists a vast diversity of values and social norms; thus, people tend to differ in their acceptance of new technologies and methods. Consequently, such diversity poses a considerable challenge in the adoption of Industry 5.0 since individuals come from different backgrounds and hold distinct viewpoints that can influence their perspectives.

In Industry 5.0, the integration hurdle poses a challenge to its stakeholders, customers to SMEs. Coping with technology advancements can also make research and development more complex, given the interdisciplinary research fields and intricate systems in play. Incorporating innovation policies that prioritize the ecosystem poses its own set of difficulties. The industry's rapidly shifting climate necessitates agile and results-driven approaches, which presents yet another challenge. The adoption of adaptable and flexible Industry 5.0 innovation methodologies is, therefore, imperative. To thrive in Industry 5.0, businesses must boost productivity through significant capital investments. However, this presents challenges for those with limited resources. Before taking the plunge, companies must thoroughly weigh the rewards and hazards of embracing these technologies.

The connection between Industry 5.0 and eye tracking systems lies in the fact that both areas aim at human-artificial intelligence cooperation and improving the

efficiency of work processes and can be fundamental elements of the future manufacturing and technological environment. Eye movement tracking systems can also be used during the examination of complex cognitive processes such as programming [31-33], with the support of which the efficiency of the process can be improved and expanded using artificial intelligence. Immersive VR [34] is, therefore, compatible with the principles of Industry 5.0 and enables effective collaboration between people and intelligent systems, increasing flexibility and innovation in production and work processes.

Digitalization and IoT devices pose a major problem for Industry 5.0 - security. The use of heterogeneous data management and cloud services exacerbates the issue as the number of vulnerabilities rises with them. Data security is a crucial aspect of Industry 5.0, where mutual trust among various stakeholders like IoT nodes, machines, and communication nodes is established through authentication. Data integrity is also vital as control commands and monitoring data pass through third-party networks. System performance must not be harmed while ensuring integrity enforcement. Privacy and data protection are key considerations in Industry 5.0. The advanced cognitive capabilities of manufacturing processes give rise to the potential for highly customized services, but this also brings ethical issues and challenges in safeguarding privacy during data collection.

In order to reintegrate human resources into the production line, effective training is required for both humans and machines to successfully cooperate. The challenge lies in scaling users and production processes, particularly in the realm of human-robot collaboration. This can prove to be a hurdle for the seamless partnership between human intelligence and machines. AI's ethical concerns shouldn't be disregarded. Every application of AI calls on us to scrutinize the advantages and social implications. Ethical repercussions also take a critical place for success. Finally, ethical matters are the last piece of the puzzle. The measurement of environmental and social value remains an unreliable quest for Industry 5.0, despite its goal of creating such values. For organizations seeking to evaluate the efficacy of their sustainability initiatives, this presents a challenge. Industry 5.0 requires more skilled jobs and these are mainly focused on product customisation, with a strong emphasis on increasing customer satisfaction. In Industry 5.0, the majority of the production process will still be automated, but the real-time processed data from machines will provide the opportunity to collaborate with highly skilled professionals [37] [38]. Another key benefit of Industry 5.0 could be the use of greener solutions through people working together to achieve pollution-free manufacturing processes, as opposed to purely manufacturing-centric solutions.

Conclusions

Industry 5.0 relies on smart machines that maximise flexibility and sustainability, while leveraging human-machine collaboration. While Industry 4.0 focuses on technologies such as the Internet of Things or big data, Industry 5.0 focuses on human, environmental and social aspects. In this respect, Industry 5.0 complements

the achievements of Industry 4.0 and does not necessarily replace humans but promotes human-machine collaboration. This will allow humans to focus primarily not on performing parts of the control, but to incorporate human critical thinking and adaptability, while still taking advantage of the accuracy and repeatability of machines.

Technological development is no longer the sole focus of Industry 5.0, which now prioritizes social values and human involvement. Through human-machine collaboration, the production processes can be customized to provide personalized customer experiences. With an emphasis on environmental responsibility and social improvement, Industry 5.0 pioneers a paradigm shift.

Industry 5.0's application of technology and innovation allows companies to meet customers' distinctive demands while adjusting to an environment that is quickly evolving. Transforming the work atmosphere is accomplished through focusing on individuals and their growth. Ongoing learning and training play a significant role in workforce development and culture.

Industry 5.0 harnesses the unique creativity of human experts to work efficiently, smartly and accurately with machines. Many tech professionals believe that Industry 5.0 will bring back human intervention and combine high-speed and accurate machines with the critical, cognitive thinking of humans. Industry 5.0 can improve the quality of production by assigning repetitive and monotonous tasks to robots/machines and critical thinking tasks to humans.

Industry 5.0 poses many obstacles, including the incorporation of modern technology, managing moral dilemmas, and maintaining a symbiotic relationship between man and machine. To overcome these hurdles, it is crucial for industries to collaborate more closely and funnel resources into further research and development. The future of industry is set to integrate human values and technological innovation to create sustainable and human-centered industrial processes through Industry 5.0. This will pave the way for a more inclusive and sustainable society, where a delicate balance between industry growth and human values is achieved.

References

[1] B. Vogel-Heuser B., T. Bauernhansl, M. Ten Hompel: Handbuch Industrie 4.0 Bd. 4, Allgemeine Grundlagen, 2, 2017

[2] E. Oztemel, S. Gursev: Literature review of Industry 4.0 and related technologies, Journal of intelligent manufacturing, Vol. 31, 2020, pp. 127-182

[3] S. Weyer, M. Schmitt, M. Ohmer, D. Gorecky: Towards Industry 4.0-Standardization as the crucial challenge for highly modular, multi-vendor production systems, Ifac-Papersonline, Vol. 48, No. 3, 2016, pp. 579-584

[4] Y. Lu, X. Xu, L. Wang: Smart manufacturing process and system automation–a critical review of the standards and envisioned scenarios, Journal of Manufacturing Systems, Vol. 56, pp. 312-325

[5] R. Y. Zhong, X. Xu, E. Klotz, S. T. Newman: Intelligent manufacturing in the context of industry 4.0: a review, Engineering, Vol. 3, No. 5, 2017, pp. 616-630

[6] S. Huang, B. Wang, X. Li, P. Zheng, D. Mourtzis, L. Wang: Industry 5.0 and Society 5.0—Comparison, complementation and co-evolution, Journal of manufacturing systems, Vol. 64, 2022, pp. 424-428

[7] Y. Lu et al.: Outlook on human-centric manufacturing towards Industry 5.0, Journal of Manufacturing Systems, Vol. 62, 2022, pp. 612-627

[8] F. Longo, A. Padovano, S. Umbrello: Value-oriented and ethical technology engineering in industry 5.0: A human-centric perspective for the design of the factory of the future, Applied Sciences, Vol. 10, No. 12, 2020, 4182

[9] A. Amr: Future of industry 5.0 in society: Human-centric solutions, challenges and prospective research areas, Journal of Cloud Computing, Vol. 11, No. 1, 2022, pp. 1-15

[10] J. Leng et al.: (2022). Industry 5.0: Prospect and retrospect. Journal of Manufacturing Systems, Vol. 65, 2022, pp. 279-295

[11] European Commission: Industry 5.0, Link: https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en (Accessed: 2023.08.11)

[12] M. Rada: INDUSTRY 5.0 definition, Link: https://michael-rada.medium.com/industry-5-0-definition-6a2f9922dc48 (Accessed: 2023.08.11)

[13] S. Nahavandi: Industry 5.0—A human-centric solution, Sustainability, Vol. 11, No. 16, 2019, 4371

[14] J. Kraaijenbrink: What Is Industry 5.0 And How It Will Radically Change Your Business Strategy?, Forbes, 2022, Link: https://shorturl.at/AMNZ7 (Accessed: 2023.08.11)

[15] MOMENTA: Industry 5.0 - Sustainability, Human-Centric, and Resilience, Link: https://www.momenta.one/industry5.0 (Accessed: 2023.08.11)

[16] Nexus Integra: Industry 5.0: the new revolution, 2022 Link: https://nexusintegra.io/industry-5-0-the-new-revolution/ (Accessed: 2023.08.11)

[17] J. Jardine: Industry 5.0: Top 3 Things You Need to Know, MasterControl, 2020, Link: https://www.mastercontrol.com/gxp-lifeline/3-things-you-need-to-know-about-industry-5.0/ (Accessed: 2023.08.11)

[18] M. Ruggieri: The innovation behind the fifth industrial revolution, Manufacturer, 2022, Link: https://www.themanufacturer.com/articles/the-innovation-behind-the-industrial-revolution/ (Accessed: 2023.08.11)

[19] TWI: What is Industry 5.0? (TOP 5 things you need to know), Link: https://www.twi-global.com/technical-knowledge/faqs/industry-5-0#WhatisIndustry50 (Accessed: 2023.08.11)

[19] P. K. R. Maddikunta et al: Industry 5.0: A survey on enabling technologies and potential applications, Journal of Industrial Information Integration, Vol. 26, 2022, 100257

[20] X. Xu, Y. Lu, B. Vogel-Heuser, L. Wang: Industry 4.0 and Industry 5.0—Inception, conception and perception, Journal of Manufacturing Systems, Vol. 61, 2021, pp. 530-535

[21] M. Javaid, A. Haleem, R. P. Singh, M. I. U. Haq, A. Raina, R. Suman: Industry 5.0: Potential applications in COVID-19, Journal of Industrial Integration and Management, Vol. 5, No. 4, 2020, pp. 507-530

[22] O. A, ElFar et al: Prospects of Industry 5.0 in algae: Customization of production and new advance technology for clean bioenergy generation, Energy Conversion and Management, Vol. X, No. 10, 2021, 100048

[23] M. Javaid, M., A. Haleem: Critical components of Industry 5.0 towards a successful adoption in the field of manufacturing, Journal of Industrial Integration and Management, Vol. 5, No. 3, 2020, 327-348

[24] M. Abdel-Basset, G. Manogaran, A. Gamal, V. Chang: A novel intelligent medical decision support model based on soft computing and IoT, IEEE Internet of Things Journal, Vol. 7, No. 5, 2019, pp. 4160-4170

[25] F. Aslam, W. Aimin, M. Li, K. Ur Rehman: Innovation in the era of IoT and industry 5.0: Absolute innovation management (AIM) framework, Information, Vol. 11, No. 2, 2020, 124

[26] Choi, T. M., Kumar, S., Yue, X., & Chan, H. L. (2022) Disruptive technologies and operations management in the Industry 4.0 era and beyond. Production and Operations Management, 31(1), 9-31

[27] P. Fraga-Lamas, S. I. Lopes, T. M. Fernández-Caramés: Green IoT and edge AI as key technological enablers for a sustainable digital transition towards a smart circular economy: An industry 5.0 use case, Sensors, Vol. 21, No. 17, 2021, 5745

[28] P. M. Bednar, C. Welch: Socio-technical perspectives on smart working: Creating meaningful and sustainable systems, Information Systems Frontiers, Vol. 22, No. 2, 2020, pp. 281-298

[29] V. Potočan, M. Mulej, Z. Nedelko: Society 5.0: balancing of Industry 4.0, economic advancement and social problems. Kybernetes, Vol. 50, No. 3, 2020, pp. 794-811

[30] Y. Lu et al: Outlook on human-centric manufacturing towards Industry 5.0, Journal of Manufacturing Systems, Vol. 62, 2022, pp. 612-627

[31] É. Karl et al: ICT-enhanced STEM skills development opportunities for students, Proceedings of the XXXVIII. Kandó Conference 2022, Óbuda University, Kandó Kálmán Faculty of Electrical Engineering, 2022, pp 144-155

[32] Gy. Molnár, A. Fodor: The impact of digitalisation on modern methodological pedagogical practice, Proceedings of the XXXVIII. Kandó Konferencia, Óbudai Egyetem, pp. 125-143

[33] J. Katona: An Eye Movement Study in Unconventional Usage of Different Software Tools, Vol. 23, No. 3, 2023, 3823

[34] J. Katona: Examination of the advantage of the clean code technique by analyzing eye movement parameters. In Proceedings of ISER International Conference, Vol. 25, 2022, p. 26

[35] J. Katona: Analyse the readability of LINQ code using an eye-tracking-based evaluation. Acta Polytechnica Hungarica, Vol. 18, 2021, pp. 193-215

[36] A. Dæhlen: Towards Developing an Immersive Virtual Reality Applications for Supporting Vision Screening – A User Study, Journal of Applied Technical and Educational Sciences, Vol. 12, No. 4, Art No: 330

[37] Gy. Molnár: Pedagogy, innovation, technology, digital culture - new directions for digitalisation, Typotex, 2022, p 126

[38] H. Ildikó et al: Teachers' Digital Skills and Methodological Characteristics of Online Education, International Journal of Engineering Pedagogy, Vol. 13, No. 4, 2023, pp. 50-65