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TECHNOLOGY IN INDUSTRY 5.0: CRITICAL COMPONENTS AND THEIR IMPACT

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Abstract: *Industrial revolutions have always brought about major changes in the life of mankind. The Fourth Industrial Revolution has revolutionized industrial production through digitalization, but has also had a major impact on service processes. However, the so-called Industry 4.0 technologies applied in the context of the fourth industrial revolution also allow new goals to be achieved that were not yet clearly defined in the paradigm of the fourth industrial revolution: sustainability, resiliency, and human-centricity. In this article, the author seeks to answer the questions of what existing technologies can be used to achieve the goals of sustainability, resiliency, and human-centricity, and what are the main research directions that can be used to develop a sustainable production and service environment.*

Keywords: *Industry 5.0, social value, Social 5.0, human progress, extended operator, sustainability, resilience, simulation and optimization*

1. INTRODUCTION

As climate.gov stated [1], the "Earth's temperature has risen by an average of 0.06° Celsius per decade since 1850, and the rate of warming since 1982 is more than three times as fast: 0.20° C per decade." The World Food Program stated, that about 345 million people were food insecure in 2023 – more than twice as many as in 2020. Approximately 45% of deaths in children under the age of five are associated with undernutrition [2]. In addition to climate change, poverty and starvation, there are many other globalization challenges that Industry 5.0 can help address.

Industry 5.0 focuses on integrating human creativity and intelligence with state-of-the art technologies and solutions such as artificial intelligence (AI), robotics, automation and digitalization, creating a human-centric approach that enhances human capabilities rather than replacing them [3]. This collaboration between humans and machines can lead to innovation and creativity in many ways. The main object of Industry 5.0 is to develop more sustainable, available and resilient industrial solutions in the field of production and services by implementing new technologies that can reduce waste and optimize resource use including energy and materials [4]. This approach helps industries better adapt to disruptions such as pandemics or climate change [5]. Furthermore, the integration of advanced technologies makes industries more appealing to skilled human resources by providing a challenging and engaging work environment, which helps retain talent and increases job satisfaction [3]. Industry 5.0 supports the transition to a circular economy, enhancing environmental sustainability and improving economic performance and cost efficiency through more efficient and competitive practices [6]. Collaboration between humans and AI-powered robots enables rapid prototyping and continuous innovation with minimal risk. Overall, Industry 5.0 ensures that technological progress aligns with human needs and societal goals, promoting a more inclusive and sustainable industrial future.

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In this paper, the author investigate how novel technologies can be used to improve sustainability, resilience and human. To this end, the author summarizes the implications of Industry 5.0 based on a systematic literature review.

2. MATERIALS AND METHODS

Within the frame of this chapter, the research results in the field of Industry 5.0 are summarized. This section includes both descriptive and content analysis. Within the frame of the literature review, Scopus was used to identify the most important scientific results regarding Industry 5.0. The systematic literature review focuses on the transition from Industry 4.0 to Industry 5.0 and highlights the role and impact of new technology on economic, social, and environmental aspects.

Firstly, the relevant terms must be defined. In this first crucial phase I have chosen a simply keyword: "Industry 5.0" to find a wide range of articles to perform a descriptive analysis of articles. Initially, 1949 articles were identified. The systematic literature review was conducted in June 2024; therefore, new articles may have been published since then.

As Figure 1 shows, "Industry 5.0" has been researched in the past 6 years. The first article in this field was published in 2018 focusing on the birth of Industry 5.0 and next generation technology policies [7]. The number of published papers focusing on the birth and development of Industry 5.0 has been significantly increased in the last years; it shows the importance of this research field.

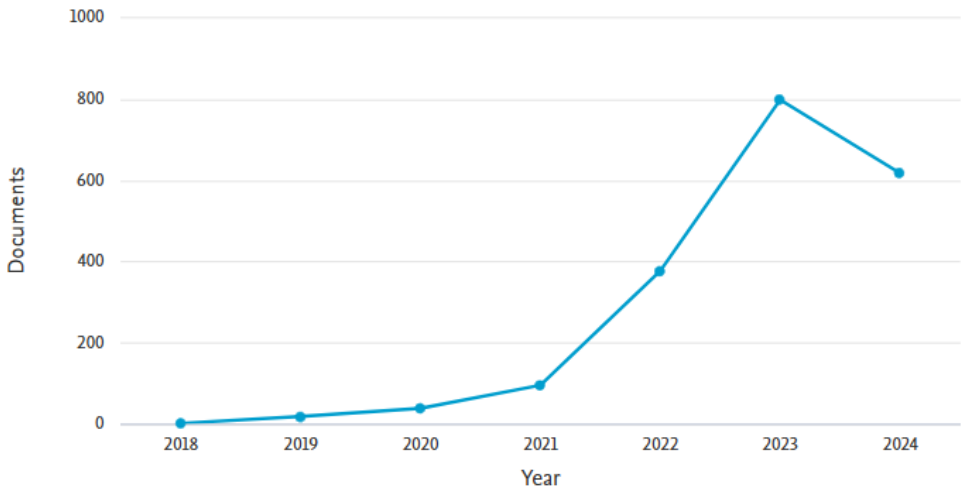

Figure 1. *Published articles per year in the field of Industry 5.0 resulted by a Scopus search (Source: www.scopus.com)*

We can analyze the distribution of published articles per year and per source, a shown in Figure 2.

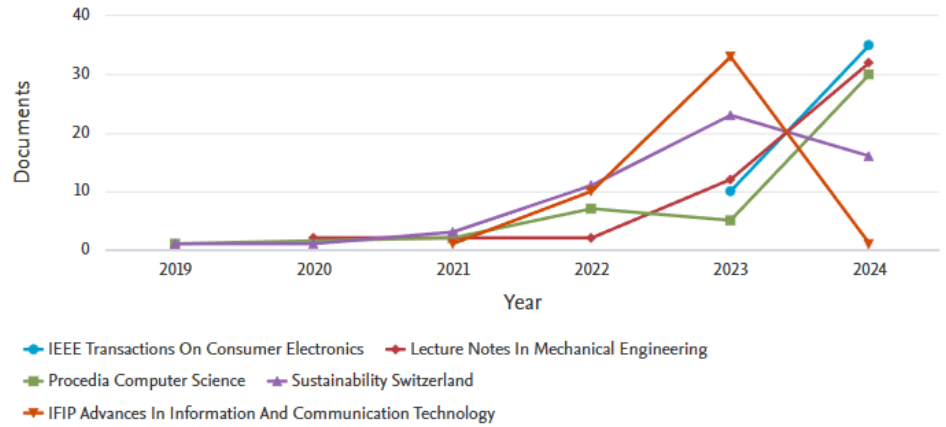

Figure 2. *Published articles per year per source in the field of Industry 5.0 resulted by a Scopus search (Source: www.scopus.com)*

It can be seen, that a wide range of articles in the field of facility location has been published in five scientific journals: IEEE Transactions on Consumer Electronics, Lecture Notes in Mechanical Engineering, Procedia Computer Sciences, Sustainability and IFIP Advances in Information and Communication Technology. The title and the main topic of these scientific journals shows, that Industry 5.0 covers interdisciplinary sciences. The CiteScore publication is shown in Figure 3.

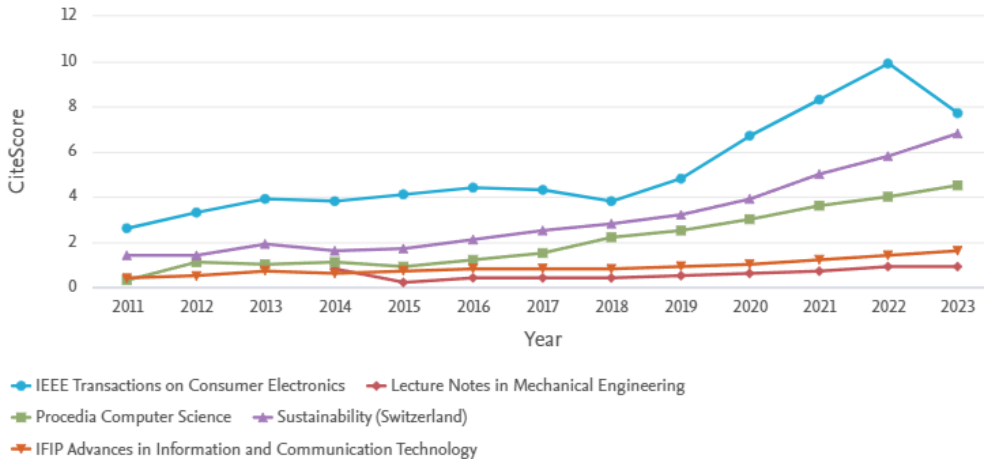

Figure 3. *CiteScore publication per year in the field of Industry 5.0 resulted by a Scopus search (Source: www.scopus.com)*

Figure 4 shows the distribution of articles by the authors, publishing a huge number of articles. It can be seen, that 8 authors have been published 10 or more articles related to Industry 5.0, which shows, that there is a worldwide research expert group in the field of Industry 5.0.

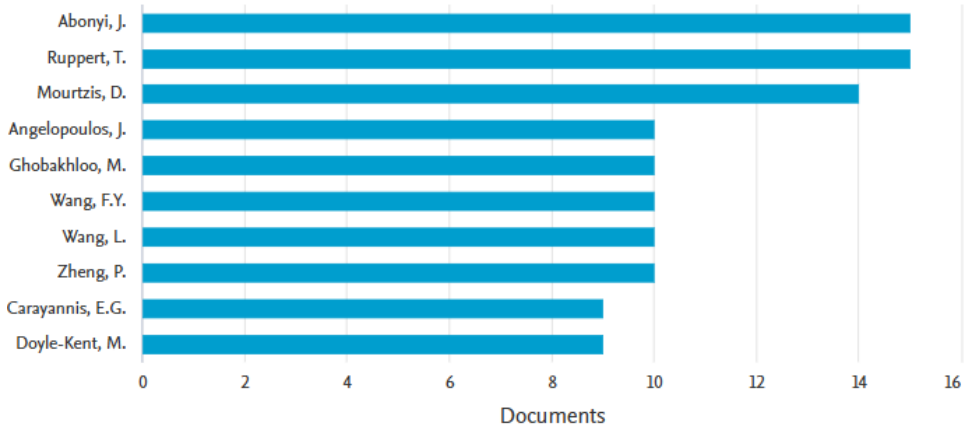

Figure 4. *Published articles per authors related to Industry 5.0 resulted by a Scopus search (Source: www.scopus.com)*

As Figure 5 shows, the affiliation of the authors is very different, including universities and research institutes in Asia, Europe and Amerika.

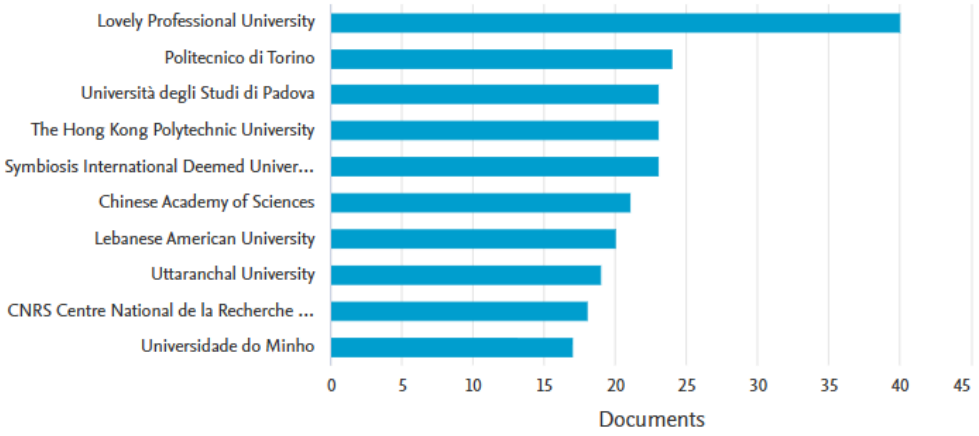

Figure 5. *Published articles per affiliation of authors related to Industry 5.0 resulted by a Scopus search (Source: www.scopus.com)*

Most of the research results have been published in journal articles, but a significant number have been published in conference proceedings and books, as shown in Figure 6. There are also the occasional editorials, erratum, notes, letters and short surveys.

The analysis of the subject area of research works shows (see Figure 7), that the most important subject areas in the Scopus are the followings: computer science, engineering, business, mathematics, decision sciences, social sciences, econometrics, energy, environmental sciences and materials science.

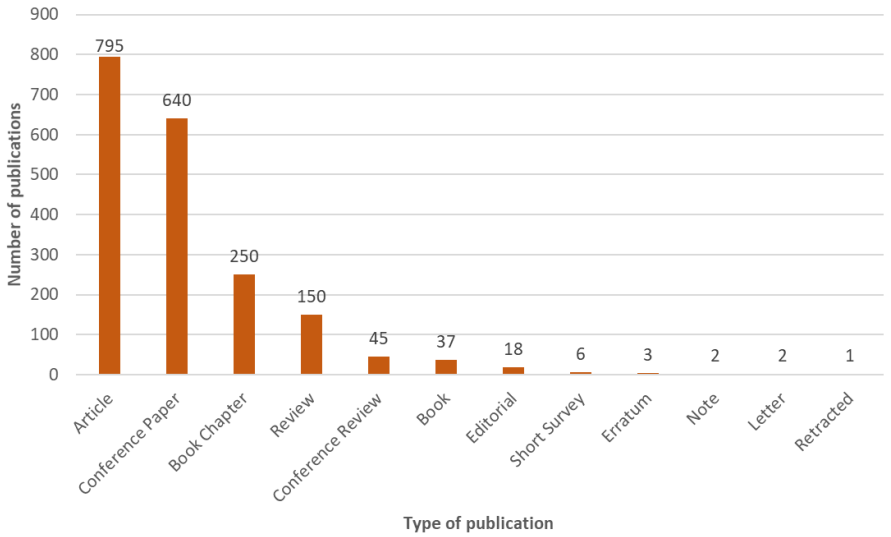

Figure 6. *Published articles by type in the field of facility location resulted by a Scopus search (Source: www.scopus.com)*

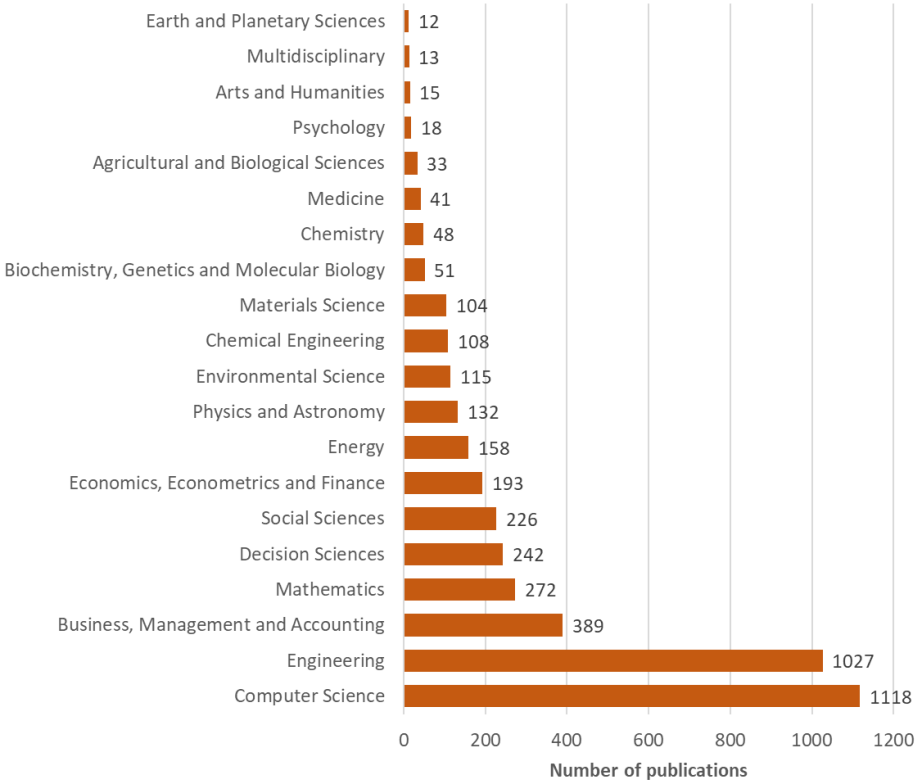

Figure 7. *Published articles by subject area related to Industry 5.0 resulted by a Scopus search (Source: www.scopus.com)*

The next phase of the literature review is the content analysis, where the initial articles are filtered using additional keywords of Scopus. As Wang mentioned in his research focusing on intelligent control in today's industrial processes [8], the rapid rising of artificial intelligence solutions and tools has a great impact on Industry 4.0 solutions, but it also influences the impact of shift from Industry 4,0 to Industry 5.0, where the main paradigm is to move from big models to foundation control and foundation management. These AI tools and solutions include ChatGPT and DALL-E as generative AI tools, qualifier.ai and apollo.io as AI for sales and marketing, Drift and NICE CXone SmartAssist Powered by Amelia as AI for customer services, Leena AI and Fetcher.ai for human resource management or Fireflies and Duet AI for meeting organization [9].

Wang et al. [10] discuss in their research work, that a 6S roadmap can lead to the transformation of cyber-physical systems (Industry 4.0) to cyber-physical-social systems (Industry 5.0). This 6S model includes the following main milestones: "Safe in physical spaces, Secure in cyberspaces, Sustainable in ecology, Sensitive in individual privacy and rights, Service for all, and Smartness of all [10]"

Ghobakloo et al. discusses the problems of transformation of Industry 4.0 to Industry 5.0 [11] and highlights the importance of sustainability focusing on stakeholders, government and policy makers. This approach shows the importance f eco-innovation and sustainable value network reformation.

Karmaker et al. discuss the role of Industry 5.0 in post-pandemic supply chain solutions [12]. They identify the challenges and prioritized them using Best-Worst-Method. The prioritized challenges were analyzed by Interpretive Structural Modelling and the analysis resulted, that financial support including tax reduction and short loans plays an important role in the improved sustainability of value chains and supply chain solutions.

Raja et al. [13] suggested to call the next industrial revolution Industry 4.0S, where S is for sustainability. The researchers concluded that the next step of industrial revolutions will be the collaboration of humans with digital technologies, where economic, social, and environmental aspect are taken into consideration, but today it is early to speak about Industry 5.0 and we should focus on sustainability aspect in Industry 4.0 and use the available technologies to improve social and environmental sustainability.

Nayeri et al. [14] discusses the sustainability, resiliency, and human-centricity aspect of Industry 5.0. They propose a novel decision-making framework to investigate a responsive supply chain named responsive Supply Chain 5.0 for healthcare systems. They show, that a wide range of decision making methodologies can be used, including Fuzzy VLSE, Analytic Hierarchy Process or the traditional Best-Worst Method.

Ivanov [15] concluded in his research on viability-based integration of the resilience, sustainability, and human-centricity perspectives, that "the major technological principles of Industry 5.0 are collaboration, coordination, communication, automation, data analytics processing, and identification … Industry 5.0 covers organization, management, technology, and performance assessment and … Industry 5.0 spans three levels: society level, network level, and plant level."

Adel defines in a research on human-centric solutions, challenges and prospective research areas [16] that Industry 5.0 will integrate cyber-physical cognitive systems, green manufacturing, cultural collaboration and mass customization. In this research, the focus is on people working with robots and smart machines, because robots can support human operators to work better by leveraging advanced technologies, including Internet of Things, identification systems, digital twin, etc.

Cillo et al. [17] rethinks companies' culture through knowledge management lens during Industry 5.0 transition and concluded, that companies engaged in diversity policies, inclusion practices and people empowerment through education have higher chance to improve profitability.

An integrated approach is proposed by Kasinathan et al. [18] in a research focusing on realization of sustainable development goals with disruptive technologies by integrating Industry 5.0, Society 5.0, Smart Cities and Villages. In their research they propose an integrated framework for including state-of-the art technologies (artificial intelligence, big data analytics, drones, robotics, cybersecurity, process automation, cloud computing, Internet of Things, augmented reality, virtual reality, autonomous vehicles) to establish the concepts of Industry 5.0 and Society 5.0 integrated into smart cities and villages. However, Kasinathan mentioned cloud computing as new age technology [18], but other sources [14] discuss fog and edge computing as new age technology in the Industry 5.0 era.

Khan et al. [19] highlight the importance of 6G communication in Industry 5.0 and they show, that "automotive-Industry 5.0 will use emerging 6G communications to provide robust, computationally intelligent, and energy-efficient data sharing among various onboard sensors, vehicles, and other intelligent transportation system entities." They propose nonorthogonal multiple access (NOMA) and backscatter communications as two new age technologies of 6G communications, which is especially important in the Automotive Industry 5.0 from energy efficiency point of view.

Leng et al., [20] discusses the pros and cons of Industry 5.0 and they concluded, that in The Industry 5.0 humans' well-being is in the center of manufacturing systems which can lead to the sustainable development of all humanity.

A strategy roadmap for delivering sustainability values was developed by Ghobakhloo et al. [21]. They propose a novel reference model for Industry 5.0, which integrates human centricity, socio-environmental sustainability, and resilience. In this research, 16 sustainable development functions are defined, including circular intelligent products (circular gentelligent products), intelligent automation, operational and resource efficiency (resource includes energy and materials), renewable integration, service orientation and personalization (mass customization) or value network integration through sustainable thinking.

Yin and Yu [22] proposes a novel approach to help production companies find external partners to improve their digital green innovation performance through external knowledge search partner selection.

Paradigm shift can be recognized while observing the transition from Industry 4.0 to Industry 5.0, as the analysis of paradigm shift for the people, organization and technology by Zizic et al. [23] shows. Their general conclusion is that there is a significant change of the main research aims from sustainability towards human-centricity. This change means in the case of operators, that the manual work is transformed through computer assisted work into work with augmented technologies. Other transformation aspect can be defined in the case of decision making, where the experience-based decision making is transformed into information based decision making [23] including real-time decision making [24, 25].

Huang et al. [26] focuses in their research on the comparison between Industry 5.0 and Society 5.0. They identified the main corresponding foundational arguments about Industry 5.0 and Society 5.0 and these can accelerate the development of Industry 5.0 and Society 5.0. These aspects are also discussed by Jefron et al. [27] focusing on the major implications for smart logistics and Grabowska et al. [28] focusing on humanization and sustainability from scientometrics point of view.

The technological aspects of Industry 5.0 and the transformation from Industry 4.0 to Industry 4.0S or Industry 5.0 are extensively discussed in a wide range of researches, which are focusing on the following main state-of-the art technologies:

- Virtual reality and digital twin are proposed by Wang et al. [29] for Building Information Modeling (BIM),
- UAV based long range environment monitoring systems is proposed by Sharma et al. [30] to support smart city infrastructure,
- An IoT based Absolute Innovation Management (AIM) is proposed by Aslam et al. [31] to support innovation in Industry 5.0 era,
- The smart circular economy can be supported by green IoT and edge artificial intelligence, as mentioned by Fraga-Lamas et al. [32],
- Human-robot interaction and the application of cobots is discussed by Coronado et al. [33] and Kaassinen et al. [34] focusing on the human-centered factors, measures and metrics in the Industry 5.0 era,
- The future direction of application of blockchain technology is discussed by Veram et al. [35].

As Maddikunta et al. [36] summarizes, the above-mentioned enabling technologies are available in the Industry 4.0 era, and these are also the key technologies in the Industry 5.0 era, where economic, social, and environmental aspect must be highlighted.

The optimization plays also an important role in complex, global supply chain solutions, but it is also important in the case of in-plant logistics, because the optimization focuses both on cost efficiency and sustainability [37, 38]

3. RESULTS AND CONCLUSIONS

The industrial revolutions have always represented a significant step in human history, resulting in an improvement in the quality of human existence. This was seen with the steam engine in the first industrial revolution and is being experienced through digitalization in the fourth industrial revolution, where the impact of modern technologies to ensure that globalization and the impact of globalization issues on productivity can be secured even in uncertain operating environments is well understood. However, in today's increasingly global crisis, economic efficiency, reliability and productivity are not enough; environmental and sustainability aspects need to be taken into account in order to enhance human centricity.

Within the frame of this article, the authors focuses on the main research direction between 2018 and 2024 and identifies the main characteristic of Industry 5.0, which can be summarized as follows:

- Industry 5.0 focuses on sustainability, resiliency, and human-centricity.
- New technologies are available to improve sustainability from resources point of view. Resources includes energy, materials, machines and human resources.
- However, Industry 5.0 focuses on human centricity, but this aspect does not contradict the fact that an appropriate framework must be defined for the efficient cooperation and collaboration of human operators and machines (robots).
- There are significant changes in decision making. We are witnessing a shift from experience based decision making to an information based decision making, where real-time decisions become more and more important, and these real-time decisions can significantly influence human-centricity.

- Virtual and augmented reality has significant implications and impact on human-centricity, because VR/AR solutions can significantly lead to positive changes in working conditions and trainings, especially in the case of dangerous working environment.

REFERENCES

[1] Lindsey, R. & Dahlmann, L. (2024). *Climate Change: Global Temperature*. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature, Accessed: 15.05.2024

[2] Children International. *Facts about poverty*. Retrieved from https://www.children.org/global-poverty/global-poverty-facts/facts-about-world-poverty-and-hunger, Accessed: 20.06.2024

[3] SAP Insights. *Industry 5.0: Adding the human edge to industry 4.0.* Retrieved from https://www.sap.com/insights/industry-5-0.html, Accessed: 15.05.2024

[4] HQSoftwarelab. *Industry 5.0: Intelligent Automation of Manufacturing*. Retrieved from https://hqsoftwarelab.com/blog/industry-5-0/, Accessed: 15.05.2024

[5] European Commission. *Industry 5.0. What this approach is focused on, how it will be achieved and how it is already being implemented*. Retrieved from https://research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en, Accessed: 15.05.2024

[6] Scoop. *Industry 5.0 – the essence and reasons why it gets more attention*. Retrieved from https://www.i-scoop.eu/industry-4-0/industry-5-0/, Accessed: 15.05.2024

[7] Vural, Ö. & Nezih, H. (2018). Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "the Internet of Things" and Next-Generation Technology Policy. *OMICS A Journal of Integrative Biology*, **22**(1), 65-76, https://doi.org/10.1089/omi.2017.0194

[8] Wang, F. Y. (2023). New Control Paradigm for Industry 5.0: From Big Models to Foundation Control and Management. *IEEE/CAA Journal of Automatica Sinica*, **10**(8), 1643-1646, https://doi.org/10.1109/JAS.2023.123768

[9] Davis, L. (2024). *10 AI Tools In 2024*. Retrieved from: https://www.forbes.com/advisor/business/ai-tools/, Accessed: 22.03.2024

[10] Wang, X., Yang, J., Wang, Y., Miao, Q., Wang, F.-Y., Zhao, A., Deng, J.-L., Li, L., Na, X. & Vlacic, L. (2023). Steps Toward Industry 5.0: Building '6S' Parallel Industries With Cyber-Physical-Social Intelligence. *IEEE/CAA Journal of Automatica Sinica*, **10**(8), 1692-1703, https://doi.org/10.1109/JAS.2023.123753

[11] Ghobakhloo, M., Iranmanesh, M., Morales, M. E., Nilashi, M. & Amran, A. (2023). Actions and approaches for enabling Industry 5.0-driven sustainable industrial transformation: A strategy roadmap. *Corporate Social Responsibility and Environmental Management*, **30**(3), 1473-1494, https://doi.org/10.1002/csr.2431

[12] Karmaker, C.L., Bari, A. B. M. M., Anam, M. Z., Ahmed, T., Ali, S. M., de Jesus Pacheco, D. A. & Moktadir, M. A. (2023). Industry 5.0 challenges for post-pandemic supply chain sustainability in an emerging economy. *International Journal of Production Economics*, **258**, 108806, https://doi.org/10.1016/j.ijpe.2023.108806

[13] Raja Santhi, A. & Muthuswamy, P. (2023). Industry 5.0 or industry 4.0S? Introduction to industry 4.0 and a peek into the prospective industry 5.0 technologies. *International Journal on Interactive Design and Manufacturing*, **17**(2), 947-979, https://doi.org/10.1007/s12008-023-01217-8

[14] Nayeri, S., Sazvar, Z. & Heydari, J. (2023). Towards a responsive supply chain based on the industry 5.0 dimensions: A novel decision-making method. *Expert Systems with Applications*, **213**, 119267, https://doi.org/10.1016/j.eswa.2022.119267

[15] Ivanov, D. (2023). The Industry 5.0 framework: viability-based integration of the resilience, ustainability, and human-centricity perspectives. *International Journal of Production Research*, **61**(5), 1683-1695, https://doi.org/10.1080/00207543.2022.2118892
[16] Adel, A. (2022). Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas. *Journal of Cloud Computing*, **11**(1), 40, https://doi.org/10.1186/s13677-022-00314-5
[17] Cillo, V., Gregori, G. L., Daniele, L. M., Caputo, F. & Bitbol-Saba, N. (2022). Rethinking companies' culture through knowledge management lens during Industry 5.0 transition. *Journal of Knowledge Management*, **26**(10), 2485-2498, https://doi.org/10.1108/JKM-09-2021-0718
[18] Kasinathan, P., Pugazhendhi, R., Elavarasan, R. M., Ramachandaramurthy, V. K., Ramanathan, V., Subramanian, S., Kumar, S., Nandhagopal, K., Raghavan, R. R. V., Rangasamy, S., Devendiran, R. & Alsharif, M. H. (2022). Realization of Sustainable Development Goals with Disruptive Technologies by Integrating Industry 5.0, Society 5.0, Smart Cities and Villages. *Sustainability* (Switzerland), **14**(22), 15258, https://doi.org/10.3390/su142215258
[19] Khan, W. U., Ihsan, A., Nguyen, T. N., Ali, Z. & Javed, M. A. (2022). NOMA-Enabled Backscatter Communications for Green Transportation in Automotive-Industry 5.0. *IEEE Transactions on Industrial Informatics*, **18**(11), 7862-7874, https://doi.org/10.1109/TII.2022.3161029
[20] Leng, J., Sha, W., Wang, B., Zheng, P., Zhuang, C., Liu, Q., Wuest, T., Mourtzis, D. & Wang, L. (2022). Industry 5.0: Prospect and retrospect. *Journal of Manufacturing Systems*, **65**, 279-295, https://doi.org/10.1016/j.jmsy.2022.09.017
[21] Ghobakhloo, M., Iranmanesh, M., Mubarak, M. F., Mubarik, M., Rejeb, A. & Nilashi, M. (2022). Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values. *Sustainable Production and Consumption*, **33**, 716-737, https://doi.org/10.1016/j.spc.2022.08.003
[22] Yin, S. & Yu, Y. (2022). An adoption-implementation framework of digital green knowledge to improve the performance of digital green innovation practices for industry 5.0. *Journal of Cleaner Production*, **363,** 132608, https://doi.org/10.1016/j.jclepro.2022.132608
[23] Zizic, M. C., Mladineo, M., Gjeldum, N. & Celent, L. (2022). From Industry 4.0 towards Industry 5.0: A Review and Analysis of Paradigm Shift for the People, Organization and Technology. *Energies*, **15**(14), 5221, https://doi.org/10.3390/en15145221
[24] Bányai, Á. & Bányai, T. (2022). Real-Time Maintenance Policy Optimization in Manufacturing Systems: An Energy Efficiency and Emission-Based Approach. *Sustainability*, **14**(17), 10725, https://doi.org/10.3390/su141710725
[25] Bányai, Á., Illés, B., Glistau, E., Machado, N. I. C., Tamás, P., Manzoor, F. & Bányai, T. (2019). Smart Cyber-Physical Manufacturing: Extended and Real-Time Optimization of Logistics Resources in Matrix Production. *Applied Sciences-Basel*, **9**(7), 1287, https://doi.org/10.3390/app9071287
[26] Huang, S., Wang, B., Li, X., Zheng, P., Mourtzis, D. & Wang, L. (2022). Industry 5.0 and Society 5.0—Comparison, complementation and co-evolution. *Journal of Manufacturing Systems*, **64**, 424-428, https://doi.org/10.1016/j.jmsy.2022.07.010
[27] Jefroy, N., Azarian, M. & Yu, H. (2022). Moving from Industry 4.0 to Industry 5.0: What Are the Implications for Smart Logistics? *Logistics*, 6(2), 26, https://doi.org/10.3390/logistics6020026
[28] Grabowska, S., Saniuk, S. & Gajdzik, B. (2022). Industry 5.0: improving humanization and sustainability of Industry 4.0. *Scientometrics*, **127**(6), 3117-3144, https://doi.org/10.1007/s11192-022-04370-1
[29] Wang, W., Guo, H., Li, X., Tang, S., Li, Y., Xie, L. & Lv, Z. (2022). BIM Information Integration Based VR Modeling in Digital Twins in Industry 5.0. *Journal of Industrial Information Integration*, **28**, 100351, https://doi.org/10.1016/j.jii.2022.100351

[30] Sharma, R. & Arya, R. (2022). UAV based long range environment monitoring system with Industry 5.0 perspectives for smart city infrastructure. *Computers and Industrial Engineering*, **168**, 108066, https://doi.org/10.1016/j.cie.2022.108066

[31] Aslam, F., Aimin, W., Li, M. & Rehman, K. U. (2020). Innovation in the era of IoT and industry 5.0: Absolute innovation management (AIM) framework. *Information* (Switzerland), **11**(2), 124, https://doi.org/10.3390/info11020124

[32] Fraga-Lamas, P., Lopes, S. I. & Fernández-Caramés, T. M. (2021). 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*, **21**(17), 5745, https://doi.org/10.3390/s21175745

[33] Coronado, E., Kiyokawa, T., Ricardez, G. A. G., Ramirez-Alpizar, I. G., Venture, G. & Yamanobe, N. (2022). Evaluating quality in human-robot interaction: A systematic search and classification of performance and human-centered factors, measures and metrics towards an industry 5.0. *Journal of Manufacturing Systems*, **63**, 392-410, https://doi.org/10.1016/j.jmsy.2022.04.007

[34] Kaasinen, E., Anttila, A.-H., Heikkilä, P., Laarni, J., Koskinen, H. & Väätänen, A. (2022). Smooth and Resilient Human–Machine Teamwork as an Industry 5.0 Design Challenge. *Sustainability* (Switzerland), **14**(5), 2773, https://doi.org/10.3390/su14052773

[35] Verma, A., Bhattacharya, P., Madhani, N., Trivedi, C., Bhushan, B., Tanwar, S., Sharma, G., Bokoro, P. N. & Sharma, R. (2022). Blockchain for Industry 5.0: Vision, Opportunities, Key Enablers, and Future Directions. *IEEE Access*, **10**, 69160-69199, https://doi.org/10.1109/ACCESS.2022.3186892

[36] Maddikunta, P. K. R., Pham, Q.-V., B, P., Deepa, N., Dev, K., Gadekallu, T. R., Ruby, R. & Liyanage, M. (2022). Industry 5.0: A survey on enabling technologies and potential applications. *Journal of Industrial Information Integration*, **26**, 100257, https://doi.org/10.1016/j.jii.2021.100257

[37] Veres, P. (2023). Increasing the efficiency of warehouse analysis using artificial intelligence. *Acta Logistica: International Scientific Journal about Logistics*, **10**(3), 445-451, https://doi.org/10.22306/al.v10i3.415

[38] Gulyás, M. & Veres, P. (2023). Assessment and development of the selective waste collection at the University of Miskolc. *Advanced Logistic Systems - Theory and Practice*, **17**(2), 54–60, https://doi.org/10.32971/als.2023.016