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IDENTIFICATION AND DEVELOPMENT ON NEW BUSINESS OPPORTUNITIES IN THE CONTEXT OF INDUSTRY 5.0 AND SOCIETY 5.0

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Abstract

Industry 5.0 is a term coined by the European Commission, according to which "Industry 5.0 complements the existing paradigm of Industry 4.0 by emphasizing research and innovation as drivers of the transition to a sustainable, human-centered and resilient European industry". Although the general concept of Industry 5.0 has been elaborated, its implications for future operations and supply chains have not been sufficiently explored. While Industry 4.0 defines the application of digital technologies to business infrastructure and processes, Industry 5.0 needs to make workplaces more inclusive, build resilient supply chains and adopt more sustainable ways of production. These visions point to human-machine interactions and the concept of sustainable social well-being. Rapid technological evolution has become a major challenge for organizations and societies due to the openness provided by new digital technologies, platforms and infrastructures and due to the impact of innovation on the way people work and live. With the increasing need to consider the social and environmental impact of technologies, the concept of Society 5.0 has been proposed to restore the centrality of people in the proper use of technology. In addition to identifying people, resilience and sustainability as key dimensions of Society 5.0, the paper analyzes the technological principles of Industry 5.0 (cooperation, coordination, communication, automation, data processing), the areas of organization, management, technology and impact assessment, as well as levels of society, levels of networks and factory levels.

Key words: *Industry 5.0, Society 5.0, sustainability, human-centered, resilience.*

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Introduction

The concept of Industry 5.0 has recently emerged as a vision of the industry of the future that values the protection of the environment and society. Proponents of Industry 5.0 believe that Industry 4.0 is not the right framework for achieving sustainable development. The literature acknowledges that Industry 4.0 focuses on technology-driven productivity. Although the internal productivity mechanism of Industry 4.0 improves some metrics of micro-ecological sustainability, such as production efficiency or reduction of harmful gas emissions, it cannot overcome the profit-centricity of modern economic models of production and consumption.
Critics point out that Industry 4.0 is aligned with long-standing models of neoliberal capitalism that emphasize profitability and the primacy of shareholders, intensifying some of the prevailing socio-ecological problems, such as regional inequality, environmental degradation and the fragility of the global economy. Industry 5.0 represents a transformative model that draws on the experience of Industry 4.0 and the disruptions caused by the pandemic to develop a hyper-connected industrial ecosystem that values the goals of sustainable development. In line with the European Commission's Industry 5.0 agenda for 2022, the sustainable development goals of Industry 5.0 include the inclusive development of the economic, environmental and social pillars of sustainability and their underlying micro-goals. Specifically, this phenomenon aims to promote resilience, socio-ecological sustainability and human-centeredness within the sustainable development agenda. The human-centered micro-goals of Industry 5.0 relate to employment growth, workplace dignity, employee autonomy and job satisfaction. Despite these contributions, the introduction of Industry 5.0 as a new paradigm for achieving competitive sustainability is associated with two significant controversies. First, the boundaries, basic principles and functionality of Industry 5.0 are insufficiently studied. Second, it is practically unclear how Industry 5.0 can contribute to promoting sustainable development.

Concept of Industry 5.0

The first records about Industry 5.0 were mentioned as early as 2017, and in addition to digital transition, the "green" component of the system plays an important role. The principles of Industry 5.0 do not have to affect only one organization, but the entire society. The European Union states that Industry 5.0 "puts the well-being of employees at the center of the production process and uses new technologies to ensure prosperity beyond the workplace". Therefore, it "complements the existing Industry 4.0 approach by putting research and innovation at the service of the transition towards a sustainable European industry that is resilient and people-centered". This concept benefits not only the industry, but also the employees as individuals and the entire society. This creates a more resilient system to external changes and shocks with also a "greener" approach as another characteristic.

Today, there is a general consensus on the core values of Industry 5.0 on three pillars: economic resilience, environmental sustainability and focus on people [1]. However, scientists and industry experts offer different perspectives on the definition, functionality and limits of this phenomenon. Longo and Lu believe that Industry 5.0 focuses on human-centered manufacturing, and technological progress should promote human well-being in socially smart factories [2, 3]. Viewed from the perspective of environmental sustainability, [4] explain that Industry 5.0 represents a vision of human-robot collaboration for a smart business ecosystem that promotes resource efficiency and the bioeconomy. The scope of Industry 5.0 expands beyond the manufacturing industry, including other business sectors, such as agriculture or healthcare. Alternatively, the European Commission builds on the Japanese concept of Society 5.0 and considers Industry 5.0 as a socio-economic structural shift towards a sustainable industry of the future. The European Commission indicates that Industry 5.0 should not be a chronological continuation of Industry 4.0. Instead, Industry 5.0 complements and, in many cases, extends the previous one, adding socio-ecological dimensions to Industry 4.0 [5].

In addition to the ambiguity of the definition, functionality and boundaries of Industry 5.0, the literature holistically lags behind in explaining how this phenomenon can deliver the values of sustainable development. Comparatively, Industry 4.0 is relatively well studied, and the literature provides insight into the underlying mechanism by which Industry 4.0 delivers its values, such as manufacturing productivity [6], supply chain innovation [7], sustainable manufacturing [8].

Although scholars have recently made important contributions to understanding the value of Industry 5.0, these early contributions addressed the micro implications of the phenomenon. Nevertheless, little has been done to understand how a transformative phenomenon such as Industry 5.0 and its sustainability functions can affect various micro and macro economic, environmental and social goals of sustainability. Referring to the knowledge gaps discussed, the following research questions should be answered:

1. What are the basic components and sustainability values of Industry 5.0?
2. How can Industry 5.0 provide sustainable development values?

The concept of Industry 5.0 has caused many controversies among scientists and industrial communities. Researchers have offered various reasons for the prevalence of Industry 5.0. For example, Ozdemir and Hekim defined Industry 5.0 as an evolutionary but incremental upgrade of Industry 4.0 [9]. Conversely, Nahavandi and Kumar criticized the productivity of Industry 4.0, suggesting that Industry 5.0 marks the emergence of industrial operations fueled by a new wave of disruptive technologies that promote the synergistic integration of man and machine while improving working conditions, employment and productivity [10, 11]. Although they provided different perspectives on this phenomenon, these studies agree on two fundamental characteristics of Industry 5.0.

First, they unanimously recognized that Industry 4.0 and the basic industrial transformation were associated with significant shortcomings, such as the digital

divide or technological-centricity. Recent studies clearly outline such limitations or negative impacts of Industry 4.0 on sustainability.

Second, scientists widely believe that while Industry 5.0 builds on the technological elements of Industry 4.0, it is associated with radical technological advances in cognitive artificial intelligence, energy transition technologies, and smart materials. The development of the Industry 5.0 paradigm took a new turn when it became European commission published the perspective of European technological leaders on the plan of the future European industry under the label Industry 5.0. While discussing the challenges of the term "Industry 5.0", it is suggested that "Industry 5.0 should not be understood as a replacement or an alternative, but an evolution and a logical continuation of the existing Industry 4.0 paradigm".

Although it is recognized that Industry 5.0 is centered on people and environmental values, it is suggested that this phenomenon should ensure that new technological innovations are shaped in support of socio-ecological development [12].

In 2021, the European Commission announced its Industry 5.0 agenda for a resilient, sustainable and human-centric European industry. According to this agenda, Industry 5.0 expands the paradigm of Industry 4.0 to prioritize emerging social-ecological needs [5]. At the beginning of 2022, the European Commission took a stronger position against Industry 4.0, arguing that this paradigm cannot be considered an appropriate framework for solving the prevailing climate crisis and social tensions [13]. It proposes that Industry 5.0 represents a new vision of industry, redefining the role and functionality of value chains, business models and digital transformation in a hyper-connected business environment. According to this and new academic contributions, Industry 5.0 differs from Industry 4.0 in the following ways:

- Industry 5.0 also values productivity-driven competitiveness and sustainable development;
- Industry 5.0 empowers the human workforce through promotion approach to human-centered technological development;
- Industry 5.0 promotes technological innovation in the field of environmental sustainability;
- Industry 5.0 promotes stakeholder primacy in technology management, innovation growth and performance management sustainability;
- Industry 5.0 relies on certain technologies and functional ones principles in order to extend the scope of corporate responsibility to the whole value chain.

Reference model of Industry 5.0

Industry 5.0 is still understudied, and early studies offer different concepts of this phenomenon and its basic components. In order to respond to the ambiguity and complexity of this phenomenon, the Industry 5.0 reference model was developed and presented (Figure 1).

This model provides a holistic overview, describing technological factors, principles, components and goals of the basic values of Industry 5.0. In accordance with the plan of the European Commission, Industry 5.0 is considered a socio-technological

phenomenon. Industry 5.0 is a technological phenomenon, as it focuses on technological progress and the digitization of industrial value networks. Industry 5.0 is also social phenomenon because it builds on a culture of social dialogue between stakeholders to manage and direct technological innovation to promote basic sociocultural values, such as human dignity, equality, privacy and autonomy [13].
Figure 1 shows that the enabling technologies of Industry 5.0 constitute the basic layer of the reference model. This layer consists of technologies that have emerged and matured since the third industrial revolution and which have become commercially accessible and applicable since the emergence of Industry 4.0. Smart computer-aided design and manufacturing (CADM), cloud computing, big data analytics, and enterprise planning systems are examples of technologies that enable primary production and the goals of increasing the efficiency of digitized business ecosystems within Industry 5.0 [14].

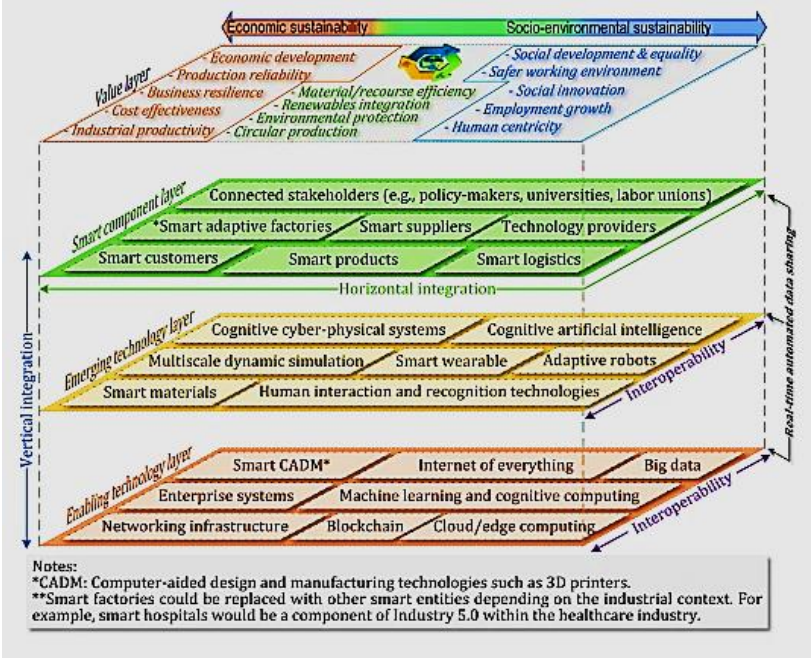

Figure 1: The reference model of Industry 5.0.

Industry 5.0 also relies on technological innovations listed under emerging technologies in the reference model to achieve the basic goals of people-centeredness, resilience and sustainability. Figure 1 shows that cognitive cyber–physical systems, cognitive artificial intelligence, and smart wearables are among the new technologies of this phenomenon.
Considering a human-centric approach to the manufacturing environment, Industry 5.0 relies on adaptive robots, cognitive cyber-physical systems, and human interaction

and recognition technology to develop human-centered solutions that prioritize the basic needs of employees while maintaining or improving productivity [15].

Regarding the resilience goal of Industry 5.0, enterprises can rely on dynamic simulation, cognitive artificial intelligence and big data to develop a digital replica of supply chain operations and identify bottlenecks, weak links, risks and imminent disruptions in order to improve the adaptability and responsiveness of networks supply. Alternatively, modern supply chains can use the Internet of Everything (IoE), blockchain, smart materials, and smart computer-aided design tools to increase operational agility and move toward new business models that support product personalization and servitization [16].

The third layer of the reference model represents the smart components of this phenomenon. Like its predecessor, Industry 5.0 represents a paradigm shift that involves digitalization of industrial value chains [17]. However, Industry 5.0 differs from Industry 4.0 because it takes a stakeholder-centric approach in defining the impact of this phenomenon and the combination of the expected value [18].

The smart component layer of the reference model consists of smart customers, suppliers, logistics, technology providers and adaptive factories, which together create a data-driven hyper-connected business ecosystem [13]. More importantly, related stakeholders, such as policy makers, universities and trade unions are necessary components of Industry 5.0. The integration of connected stakeholders is critical for Industry 5.0 because the phenomenon is primarily technology-based, and most socio-ecological values cannot be delivered without the systemic management of technology imposed by stakeholders [19]. The European Commission even believes that Industry 5.0 requires Government 5.0 to respond to the needs of policy, regulation, financing and innovation management [13].

The presented reference model is primarily applicable to the manufacturing industry, but its components can be adapted to any industrial environment, given that the ripple effects of Industry 5.0 are spreading beyond the manufacturing sector. For example, Industry 5.0 can have important implications for healthcare, and its components can be adapted to the specifics of this sector (e.g. by adding smart hospitals and adapting components of a smart adaptive factory for production of personalized health products) [15].

Two-way arrow at the top of the value layer in the reference model indicates that Industry 5.0 is not only economically driven because it systematically strives to balance economic and socio-ecological sustainability. The reference model of Industry 5.0 indicates that different aspects of economic, environmental and social sustainability within the value layer are interconnected, so synergistic complementarity between them requires stakeholders to simultaneously pursue different sustainable development goals.

Business, supply chain and economic resilience are the most emphasized goals of the economic sustainability of Industry 5.0 [1]. Within environmental sustainability, values include preserving ecological and resource integrity by promoting circular economy, carbon neutrality (net-zero), integration of renewable sources and resource efficiency [5]. The social sustainability values of Industry 5.0 include promoting a

human-centric approach to place basic human needs and rights at the center of the industrial economy, promoting social development, employment, equality and human agency [20].

In addition to enabling and emerging technologies, Industry 5.0 relies on certain techno-functional principles to deliver the intended aspect of digital transformation. As shown in the reference model, vertical integration, horizontal integration, interoperability and real-time data sharing are among the fundamental techno-functional principles of Industry 5.0. When properly developed, techno-functional principles facilitate the development of the sustainable development functions of Industry 5.0. For example, the principle of automated real-time data sharing allows smart objects and modules of Industry 5.0 components to communicate vertically or horizontally in real-time when needed. These principles also represent the basic technical conditions that allow the components of Industry 5.0 to use the basic technologies and function properly in accordance with the objectives of Industry 5.0.

Key factors of Industry 5.0

In the relevant literature, there are several key points that stand out and distinguish the transition from Industry 4.0 to Industry 5.0 and which can be used as drivers for the implementation of Industry 5.0. They can be divided into two groups:

- a human-centered approach,
- awareness of the impact on the environment.

These two groups have one thing in common – achieving a sustainable system. Each of the components brings many advantages to the production system, but also generates certain barriers.

A human-centered approach. After Industry 4.0 initiated the complete digitization and automation of repetitive human work, it created one of the biggest barriers in its implementation. It is true that many professions may disappear due to the automation of work, but the need for human resources is one of the most important components of the industry. That's why Industry 5.0 puts people at the center of the system and understands human knowledge and skills as one of the most valuable resources and a source of competitive advantage. Local governments have recognized the need for new professional staff in digital technologies, which is why the education system is also facing numerous changes. Today, there are more and more examples of "learning factories" that are, most often, part of academic institutions, but they are used not only for the education of students, but also for the education of employed professionals who accept the concept of lifelong learning and improvement.

Flexibility and modularity. Unexpected global crisis and disruptions in the supply chains have caused the modularity and flexibility of the system to become the most important goals of production companies. Another trend that emphasizes the need for flexibility is product customization, which leads to significant product variations with shorter time for preparation and production planning. This can be achieved by and at the software level advanced systems (digital twins) that control and adjust hardware (machines, robots, etc.), which is often called self-optimization. One of the hardware

solutions that enable flexibility are collaborative robots that are cost-effective, safe and flexible.

Human factors, ergonomics, well-being and ethical technology. A special focus in Industry 5.0 is given to the interaction between man and machine, which can partly be understood as a continuation of the use of collaborative robots. Ergonomics and measurement standards can be implemented in digital twins, but there is also an increased need to use specialized ergonomic software, such as Siemens Jack, ErgoPlus, VelocityEHS or SHERPA Software. The motivation of workers is also one of the key components of Industry 5.0, which can be increased not only by ergonomic design of the workplace but also by applying the principle of well-being in the working environment. Well-being principles can improve worker health and minimize the impact of stress-related psychosomatic illnesses that lead to worker absenteeism. With the increased use of artificial intelligence, certain ethical concerns have been raised. This includes the use and distribution of collected data, security issues related to cybercrime and worker safety. Therefore, the issues of reliable and ethical technology cannot only be discussed at the industrial level, but also at the level of legislative bodies.

Innovation management. Innovation is one of the leading advantages of any company that increases market competitiveness. The need for system flexibility and adaptation to market requirements and needs has placed innovation management as one of the most important organizational points of the Industry 5.0 concept. This includes the specific management of the organization's innovation process, in which people from every organizational level must be involved. A set of tools that allow employees to better understand processes and internal goals can be expanded as part of the R&D department, all with the goal of reducing production costs, increasing product quality, and shortening time to market.

Green and sustainable production. With the preservation of the climate and the reduction of the general pollution, green technologies have become the most important in every aspect of human life, including industry. Using sustainable energy sources and increasing energy efficiency is another point to be achieved with Industry 5.0, and the use of advanced technologies enables an adequate transition to green standards and their optimization in the exploitation phase. This is closely related to the concept of circular economy which encourages recycling and reuse of materials and products to reduce waste, maximize usability and minimize harmful impact on the environment. This is necessary to ultimately achieve a sustainable system that will not be subject to unexpected changes or disruptions in the market and to enable the implementation of a flexible human-centered system.

Concept if Industry 5.0 and Society 5.0

Society 5.0 [8] is a vision of a future society driven by scientific and technological innovation, with the goal of creating a human-centered, super-smart and lean society, as shown in the right circle in Figure 2, which was initiated by the Japanese government in January 2016.

Figure 2. Vision of Industry 5.0 and Society 5.0

The concept of Society 5.0 was proposed to balance economic progress with solving social problems in Japan (population aging, low birth rate and loss of competitiveness). The goal of the Society 5.0 is a human-centered super-smart society to ensure that all citizens have access to a high-quality life full of comfort and vitality by providing necessary goods and services at the required level when needed by merging cyberspace and physical space with 5G, Big data, artificial intelligence etc.
In fact, human society has gone through four transformations [21], namely hunter-gatherer society (Society 1.0), agricultural society (Society 2.0), industrial society (Society 3.0) and information society (Society 4.0), and is currently moving towards a human-centered super-smart society (Society 5.0), as shown in the upper part of Figure 3.

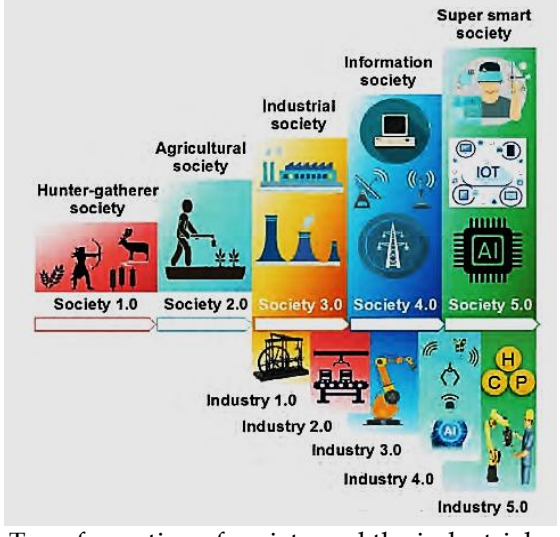

Figure 3. Transformation of society and the industrial revolution

The Industrial Revolution started from the industrial society and has seen four iterations in a relatively short time frame, empowered by advanced technologies and currently moving to the next industrial revolution , that is Industry 5.0, as shown in the lower part of Figure 3.

According to the definitions of Industry 5.0 and Society 5.0, a systematic comparison is made to better understand their relationship and interconnection, as shown in Figure 4. A comparison chart visualizes the similarities and differences between Industry 5.0 and Society 5.0 from four dimensions, including purpose, value, organization and technology.

Human-centeredness is an important element, both in Industry 5.0 and in Society 5.0. Industry 5.0 aims to activate people's creativity and evolve industry towards people-centered, resilient and sustainable prosperity, which aims to eliminate the problems that exist at the current level of industrialization and living standards. Meanwhile, the goal of Society 5.0 is to build a human-centered, super-smart and lean society with a shared comfortable and sustainable future for all. The vitality and demands of each individual will be the most important concern in the future industry and society.

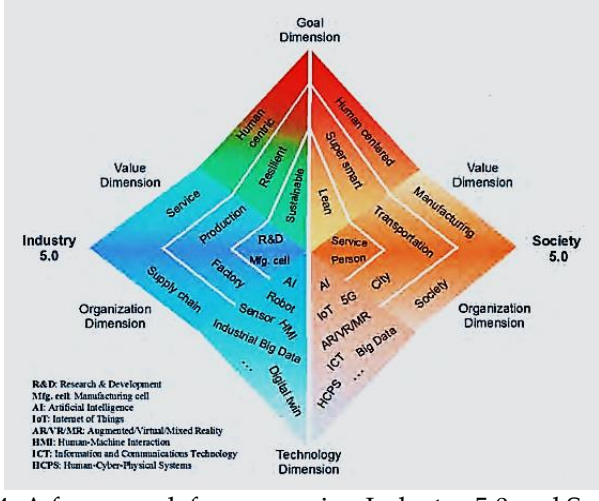

Figure 4. A framework for comparing Industry 5.0 and Society 5.0

The value chain of Industry 5.0 includes the product life cycle, which it implies innovative research and development, highly efficient production, personalized services, recycling, etc. Society 5.0 as a system of systems will create value from individualized service system, smart transportation system, intelligent production system, etc.

The organizational foundation of an industry is the production cell, factory, supply chain, etc. The resilience of industrial organizations is one of the key themes of Industry 5.0 to mitigate the challenges of uncertainty (e.g. the Covid-19 pandemic). Society 5.0 will merge cyberspace and physical space to precisely fit the demands of the individual, tightly connect the modern city and effectively solve the problem of

society in a super-smart way. In the organizational dimension, industry is the key and most active part society. This is why the speed of transformation of society accelerated after the first industrial revolution.

Industry 5.0 and Society 5.0 are heavily influenced by emerging technologies such as next-generation wireless networks, big data, artificial intelligence, digital twins, etc. The new order of a certain industry, or even an entire society, will rely on the digitalization and intellectualization trend driven by these new technologies. Every puzzle within the system (Industry 5.0 or Society 5.0) will benefit from and promote advancement in technology.

In short, although Industry 5.0 and Society 5.0 are two different concepts with different ways of realizing value through different organizational forms, both lead to human-centricity (man at the center of events) and aim to balance economic development and social issues. A typical application in the future industry is the assembly process (assembly), supported by physically and intellectually improved human abilities [22]. Also, a human-centered society will also enter a futuristic world where everyone can realize value at any time, place in a safe environment and in harmony with the natural environment without any restrictions.

Common challenges and opportunities

Industry is an integral part of society, and industrial revolutions will push it development of society. Also, the transformation of society will promote the next industrial revolution. Similar challenges and opportunities are identified in Industry 5.0 and Society 5.0, as shown in Figure 5.

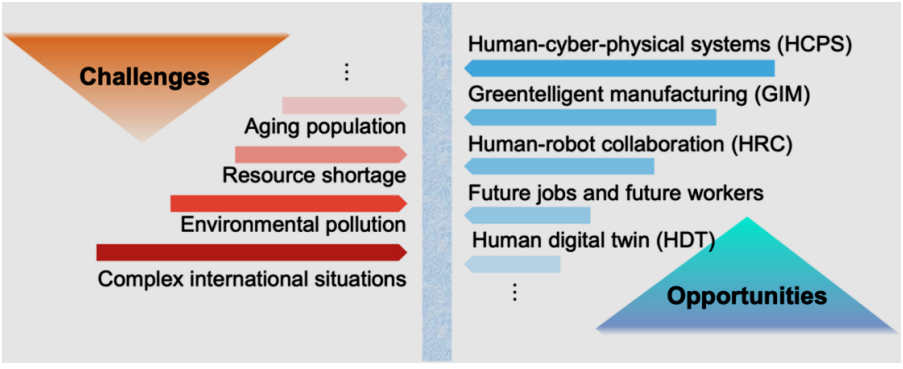

Figure 5. Summary of challenges and opportunities

Regardless of Industry 5.0 or Society 5.0, connecting cyber and physical spaces is one of the critical technologies. Man as the most creative, flexible and active factor of a system (industry or society) should be closely involved in the loop of cyber-physical interaction and decision-making process, which leads to human-cyber-physical systems (HCPS – Human-Cyber-Physical Systems) [23]. Technically, HCPS can be any

supergiant system that offers great opportunities to solve challenges in future industry and society.

A key technology enabling HCPS is digital bridging. Focusing on human, industry or society, research on human digital twins (HDT – Human Digital Twins) and human society [24] will be critical and timely (eg HDT modeling, HDT simulation, HDT theory, etc.).

Both industry and society are planned to be smarter and more sustainable. Taking production and common contents of Industry 5.0 and Society 5.0, there are many opportunities and challenges for the integration of artificial intelligence for "green production" [6], i.e. "green intelligent production" [25]. Greentelligent manufacturing (GIM) provides a promising manufacturing paradigm for solving the problems of future industry and society.

Robotics technology has been developing rapidly in Industry 4.0, so many application scenarios have been explored to improve production efficiency, quality of services etc. Human-robot collaboration (Human Robot Collaboration) [26] can be one of the most promising and challenging areas of research for the realization of a production system with a human in the center. It is a process of merging and complementing human and machine intelligence, which will break through continuous innovation capabilities, while the giant network of sensors, data storage and computing are no longer necessary [27].

Due to the revolution of industry and society, all heavy physical, repetitive (monotonous) or dangerous tasks will be automated, and many existing jobs will be eliminated, leading to unemployment and resulting in a series of serious social problems. However, it is also a spiraling upward process that will create many new jobs that require new workers (e.g., Operator 5.0 [28]), examples include data analysts, Automated Guided Vehicle (AGV) coordinators, "augmented operators," etc.

All participants, involved in this revolution, should be aware of the irreversible development trend, understand the critical time frame and adapt to the new situation in a timely and efficient manner.

Furthermore, to anticipate, respond to and recover from disruption, a smart resilient manufacturing system is described as an agile, flexible/reconfigurable system that collects and analyzes real-time operational and environmental data using smart sensor systems and descriptive, predictive and prescriptive analytics techniques.

Conclusions

So far, the concept of Industry 5.0 has not yet attracted much attention. Enterprises are still heavily engaged in Industry 4.0 or even earlier versions. Also, the "sustainability bandwagon" has just begun to roll in earnest. However, the fact that the EU is pushing companies to the next level and building its Industry 5.0 framework on three pillars provides companies with a vision of what real progress will mean in the coming years. Whether this vision will be appealing or terrifying will vary greatly between companies and people. And the degree to which it will be accepted will also vary radically. But given the current major challenges and crises we are facing, it is obvious

that Industry 5.0 is an acceptable and desirable answer. Once organizations, and as a result, societies become more people-centred, resilient and sustainable, we can expect adequate solutions to emerge.

After researching the main aspects of Society 5.0, the importance was determined direction of approach to sustainability in global projects starting with their own planning. Society 5.0 is human-centered, along with economic growth, technological development and sustainability. This new model of society is based on the fact that humanity is approaching the fifth social revolution. From the analysis, it was seen that Society 5.0, thanks to its approach, enables the development of sustainable technology without limiting prosperity. The progress of this new social concept is highlighted along with their impact on educational techniques and scenarios, including virtual systems and new work models; their impact on health care, changes for future production, including small and medium enterprises, for the development of a sustainable world, and financial and research investments.

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