

Industry 5.0 and Society 5.0—Comparison, complementation and co-evolution

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ARTICLE INFO

Keywords:

Industry 5.0

Society 5.0

Human-cyber-physical systems

Human-centricity

ABSTRACT

Recently, the futuristic industry and society have caught increasing attention, that is, on Industry 5.0 and Society 5.0. Industry 5.0 is announced by European Commission toward a sustainable, human-centric, and resilient European industry. Society 5.0 is proposed by Japan Cabinet to balance economic advancement with the resolution of social problems in Japanese society. Generally, the revolutions of industry and society have profoundly interacted with each other since the first industrial revolution. The coexistence of Industry 5.0 and Society 5.0 could raise varying confusions to be clarified and a series of questions to be answered. Therefore, we attempt to present the comparison, complementation, and co-evolution between Industry 5.0 and Society 5.0 to address the corresponding foundational arguments about Industry 5.0 and Society 5.0, which could be the basic inspiration for future investigation and discussion and accelerate the development of Industry 5.0 and Society 5.0.

1. Introduction

Industry 4.0, a technology-driven industrial revolution, conceptualizes rapid change in technology, industries, and societal patterns and processes in the past decades [1]. Industry 4.0 promotes production efficiency and quality to a higher level with the emergence and development of big data analytics [2], artificial intelligence (AI) [3], and digital twin [4]. However, Industry 4.0 is not without limitation that places more emphasis on promoting the efficiency and flexibility of industry rather than industrial sustainability and worker's welfare [5].

As a human-centric design solution where humans and cobots collaborate in a shared working environment, Industry 5.0 [5] has started gaining more attention in recent years, aiming to address the challenges exposed by Industry 4.0. Moreover, a similar concept named Society 5.0 [6] has come into being these years to solve the problems in current society, which is a futuristic super-smart society where everyone can enjoy high-quality and comfortable life through the fusion of cyberspace and physical space by fully utilizing ICT (information and communication technology). Industry 5.0 and Society 5.0 are two parallel concepts for future industry and society, respectively. These

coexisting concepts may be mentioned at the same time and result in some chaos to some extent.

The main takeaway of this discussion is that the accurate understanding of Industry 5.0 and Society 5.0 is highly important for the development of the corresponding theories, methods, and applications. It is crucial to tune the development tracks of Industry 5.0 and Society 5.0 in the very beginning to better support the operations of future industry and society. This article attempts to share the authors' view on Industry 5.0 and Society 5.0 by answering the following questions:

- What is Industry 5.0?
- What is Society 5.0?
- What are the differences between Industry 5.0 and Society 5.0?
- What are the shared fundamentals between Industry 5.0 and Society 5.0?
- What are the revolution directions of Industry 5.0 and Society 5.0?

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<https://doi.org/10.1016/j.jmansys.2022.07.010>

Received 29 June 2022; Received in revised form 22 July 2022; Accepted 22 July 2022

Available online 26 July 2022

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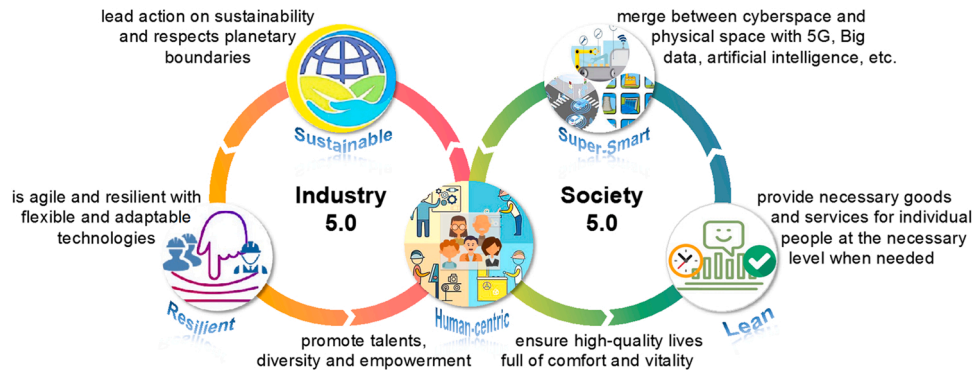


Fig. 1. Vision of Industry 5.0 and Society 5.0.

2. Conception of Industry 5.0 and Society 5.0

2.1. What is Industry 5.0 ?

Industry 5.0 is a forethoughtful concept on the future of industry towards a human-centric, sustainable, and resilient manufacturing system [7], which provides a flourishing development vision of industry as shown in the left circle of Fig. 1. The Industry 5.0 paradigm promotes systems' agility and resiliency with the utilization of flexible and adaptable technologies. Furthermore, attempts to lead action on sustainability and respects planetary boundaries and promotes talents, diversity, and empowerment.

The concept of Industry 5.0 emerged a few years ago and has been widely discussed among participants from research institutes as well as funding agencies. Extensive research is conducted on investigating and comparing the benefits and challenges to transit from Industry 4.0 to Industry 5.0 [5], including challenges, enabling technologies, and industrial applications. In fact, Industry 5.0 is already becoming part of the business landscape [8]. In 2021, European Commission suggested that the European industry shall reposition their roles in society and promote this concept in order to describe the future prosperity of European industry [9]. Industry 5.0 is understood to recognize the power of industry to achieve societal goals beyond jobs and growth, to become a resilient provider of prosperity [10] by ensuring that production respects the boundaries of our planet and places the welfare of industry technicians at the center of the manufacturing process. Industry 5.0 is predicated on the observation or assumption that Industry 4.0 places a greater emphasis on digitalization and AI-driven technologies for enhancing production efficiency and flexibility than it does on the original principles of social justice and sustainability. As a result, the idea of Industry 5.0 offers a distinctive viewpoint and emphasizes the significance of research and innovation in aiding the industry in providing long-term services to humanity inside of planetary boundaries [11].

2.2. What is Society 5.0?

Society 5.0 [12,13] is a vision of a future society guided by scientific and technological innovation, aiming to create a human-centered, super-smart, and lean society as shown in the right circle of Fig. 1, which was initiated by the Japanese government in January 2016. The concept of Society 5.0 was proposed to balance economic advancement with the resolution of social problems (e.g. aged tendency, low birth rates and lack of competitiveness) in Japan. The goal of Society 5.0 is a human-centric super-smart society to ensure all citizens can access high-quality lives full of comfort and vitality by providing necessary goods and services for individual people at the necessary level when needed through merging between cyberspace and physical space with 5 G, Big data, artificial intelligence, etc.

Actually, human society has gone through four transformations [14], that is, hunter-gatherer society (Society 1.0), agricultural society

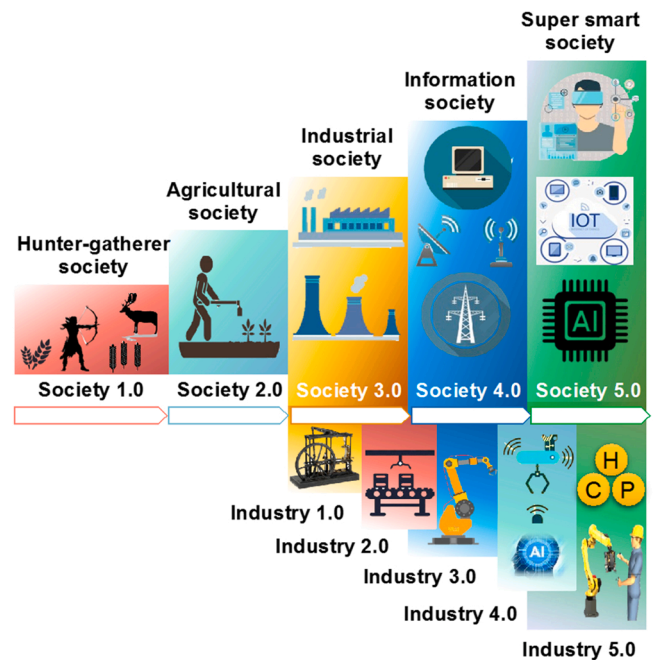


Fig. 2. Society transformation and industry evolution.

(Society 2.0), industrial society (Society 3.0), and information society (Society 4.0), and currently is leaping to a super-smart and human-centered society (Society 5.0), as shown in the upper part of Fig. 2. Industry revolution started from the industrial society and has experienced four revolutions in a relative short timeframe empowered by advanced technologies and is currently transitioning to the next industrial revolution, i.e., industry 5.0, as shown in the bottom part of Fig. 2.

3. Comparison and correlation of Industry 5.0 and Society 5.0

According to the definitions of Industry 5.0 and Society 5.0, a systematic comparison is performed to better understand their relationship and interconnection, as shown in Fig. 3. The comparison diagram visualizes the resemblance and differentiation between Industry 5.0 and Society 5.0 from four dimensions, including goal, value, organization, and technology.

Goal dimension:

Human centrality is an important element in both Industry 5.0 and Society 5.0. Industry 5.0 targets to activate the creativity of humans in industry and evolve industry to human-centric, resilient, and sustainable prosperity, which aims at eviting the problems propagating in the current level of industrialization and standards of living. Meanwhile, the

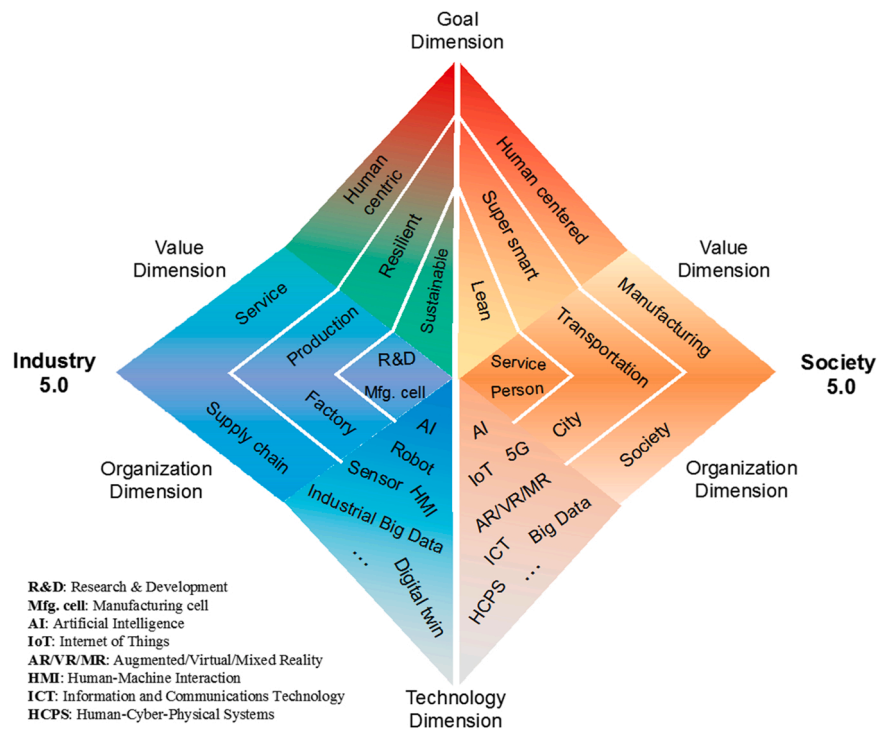


Fig. 3. Comparison framework for Industry 5.0 and Society 5.0.

goal of Society 5.0 is to construct a human-centered, super-smart, and lean society with a shared comfortable and viable future for everyone. The vitality and demand of each individual will be the most important concern in the future industry and society.

Example: In Industry 5.0, manufacturing system and production processes will be customized to accommodate the characteristics, i.e., knowledge, skill and expertise, of every worker and augment human ability by utilizing the advanced technologies. For example, robots and cobots are designed to adapt their interaction strategy if different workers join the production collaboration, AR/VR/MR can provide custom-tailored contents to train engineers and workforce, etc. Also, human-centric product and service is another feature of Industry 5.0, where humans are involved in the entire product launch process spanning from the product conceptualization and personalization to the continuous acquisition of service during the product life cycle. In Society 5.0, human-centric services are expected to spread to everyone in the society and profoundly impact the daily life of each person. For example, one can buy custom-tailored food, clothes and others conveniently. Futuristic transportation systems can provide exactly service for each driver by considering his/her age, job, destination, etc. Smart grid will optimize energy furnishing by concerning one's habit of energy usage, affordability and other factors, which could increase energy utilization and decrease operational costs for the entire society.

Value dimension:

The value chain of Industry 5.0 involves product lifecycle, including innovative R&D, highly efficient production, personalized service, recycling, etc. More and more value creations processes are designed in the downstream of the product lifecycle. Society 5.0 as a system of systems will create value from individualized service system, smart transportation system, intelligent manufacturing system, etc.

Organization dimension:

The organizational foundation of industry is manufacturing cell, factory, supply chain, etc. The resilience of industrial organizations is one of the core themes of Industry 5.0 to alleviate the challenges of uncertainties (e.g. Covid-19 pandemics). Society 5.0 will merge cyberspace and physical space to precisely anchor the demand of individual, tightly connect a modern city, and efficiently solve the society's problem

in a super-smart fashion. In organization dimension, industry is a crucial and most active constituent for society. That is why the transformation speed of society is accelerated after the first industry revolution referring to Fig. 2.

Technology dimension:

Both Industry 5.0 and Society 5.0 are profoundly impacted by the emerging technologies, such as next-generation wireless networks, big data, AI, digital twin and so on. New order of a specific industry, or even the 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 the advance in technology.

Example:

Digital twin is a key enabling technology for both Industry 5.0 and Society 5.0, which enables the connectivity between cyberspace and physical space and brings forward numerous new technologies, e.g., big data, etc. In Industry 5.0, digital twin still plays a critical role in promoting the efficiency and effectiveness of the product lifecycle [4]. For example, massive data collected from digital twin can be used to improve product design and manufacturing process improvement. The implicit fault and the complicated causality can be revealed by using data mining techniques to improve the outcomes of maintenance. The high-fidelity virtual model of digital twin can be used to simulate the manufacturing process interactively and improve user's experience by providing individualized service and training expeditiously. Similarly, in Society 5.0, digital twin can be used to enhance the operational efficiency of a smart house, a smart city, and even a smart society, where the corresponding real-time states can be obtained to support operation optimization. The potential societal problems can be monitored and analyzed in real-time to prepare effective prevention measures in advance and to avoid catastrophic social changes [15].

In short summary, although Industry 5.0 and Society 5.0 are two different concepts with different value realization paths through different organizational forms, they both lead to human centrality and aim to balance the economic development and societal issues. A typical application in the future industry is human-centric assembly supported physically and intellectually by enhanced human abilities and brain

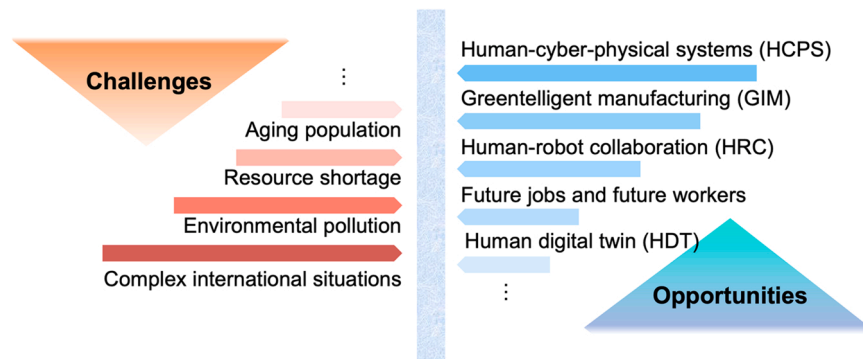


Fig. 4. Summary of challenges and opportunities.

robotics [16]. Also, a human-centric society will enter a futuristic realm where anyone can develop value at any time and place in a safe environment and according to natural environments without any limitations [17].

4. Shared challenges and opportunities

Industry is an integral part of society. The revolution of industry will push the 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 Fig. 4.

Human-cyber-physical systems (HCPS):

No matter Industry 5.0 or Society 5.0, merging cyberspace and physical space is one of the critical enabling technologies. Human as the most creative, flexible, and active factor of the system (industry or society) should be closely involved in the cyber-physical interaction loop and decision-making process, leading to human-cyber-physical systems (HCPS) [18,19]. Technically, HCPS can be any supergiant system that offers great opportunities to address challenges in future industry and society.

Human digital twin (HDT):

Digital twin is the key enabler technology of HCPS. In human-centric industry or society, the research on the digital twin of humans, human digital twin (HDT) and human society [20] will be critical and timely (e. g. HDT modeling, HDT simulation, HDT theory, etc.).

Greentelligent manufacturing (GIM):

Both industry and society are planned to be smarter and more sustainable. Taking manufacturing, a common content of Industry 5.0 and Society 5.0, as an example, there are many opportunities and challenges to integrating AI for green manufacturing [10], i.e., greentelligent manufacturing [21]. Greentelligent manufacturing provides a promising manufacturing paradigm to address the problems in future industry and society.

Human-robot collaboration (HRC):

Robotics technology is developed rapidly in Industry 4.0. Many application scenarios have been explored to promote production efficiency, service quality, etc. Human-robot collaboration (HRC) [22,23] could be one of the most promising and challenging research areas to realize the human centricity in the manufacturing system. It is a process to merge and complement human intelligence and machine intelligence, which will burst forth ceaseless innovation capability, while the giant sensory network, data storage, and computation are no longer a necessity [24].

Future jobs and future workers:

Due to the revolutions of industry and society, more and more physical or repetitive tasks will become automated, and many existing jobs will be weeded out as well, which will bring in unemployment issues and result in a series of severe social issues. However, it is also a spiraling upward process that many new jobs requiring new workers (e. g. Operator 5.0 [25]) will be created, examples include data analyst,

automated guided vehicle (AGV) coordinator, augmented operator, etc. All participants including this revolution should be aware of the irreversible development trend and grasp the critical time window to accommodate the new situation efficiently. Moreover, in order to predict, respond to, and recover from a disruption, a smart resilient manufacturing system is thus described as an agile, flexible/reconfigurable system that gathers and analyzes operational and environmental data in real time using smart sensor systems and descriptive, predictive, and prescriptive analytics techniques.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work is supported by the Zhejiang University Hundreds of Talents Program (No. 0020886).

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