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Examining the Literature on Industry 4.0 and Society 5.0's Prospects and Pitfalls

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Abstract

As a result of advancements in operational efficiency and the creation and implementation of new business models, services, and products, the manufacturing and production systems of the modern period have been dubbed "Industry 4.0." The primary objective for Industry 4.0 was to enhance the manufacturing systems' eco-friendliness and productivity. As a corollary, system enhancements were prioritised via both digitization and digitalization. However, the focus of the present technological progress is more on systems and machines than on humans. As a result, several nations have already started coordinating efforts to bring about Industry 5.0, a term referring to the design and development of human-centric technologies, systems, and services. Industry 5.0 will have far-reaching effects, resulting in a new social order known as Society 5.0. Tools and technologies developed within the context of Industry 4.0 will be designed with social and human factors in mind. For this reason, the next technological phase, dubbed Industry 5.0 and a subset of Society 5.0, will prioritise human well-being and environmental sustainability. Human-centered, resilient, and sustainable design will be at the forefront of Industry 5.0, which will expand upon the groundwork built by the previous generation. Therefore, the authors of this study want to give sufficient justification for thinking about Industry 5.0 as a framework for allowing industry and developing society trends and requirements to coexist via a critical literature assessment. Additionally, this study contributes by laying out a plan for how to go from the current Industry 4.0 to the future Society 5.0.

Keywords: Industry 5.0; Society 5.0; human-centricity; resilience; sustainability

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INTRODUCTION

Ever since the dawn of the Industrial Revolution, people have known that technology can be a tool for progress (Industry 1.0). Production of mechanical power from low-tech sources like water, steam, and fossil fuels marked the beginning of the First Industrial Revolution, which dates back to the late 18th century. Electrical energy was chosen by mass-producing companies that employed assembly lines in the 1870s, marking the beginning of the second industrial revolution (Industry 2.0). Industry 3.0, which began in the 1970s, promoted the idea of applying automation to industrial sectors via the use of electronics and IT (IT). The fourth wave of the industrial revolution (Industry 4.0) makes use of the IoT, cloud computing, and AI to enable the creation of Smart Cyber-Physical Systems (CPS), which act as a bridge between the digital and physical worlds in real time [1,2]. As a conceptual framework, Industry 4.0 (I4.0) captures the dramatic transformations in technology, industry, and social patterns and processes that have occurred over the last decade. Production efficiency and elevated product and service quality are encouraged by the I4.0 framework thanks to the advent and development of foundational technologies like big data analytics, artificial intelligence, and digital twins [3]. However, there are also constraints within the I4.0 framework, as engineers have primarily focused on the technological evolution of manufacturing and production systems and networks (digitization and digitalization), putting emphasis on industrial flexibility and efficiency rather than industrial sustainability and worker welfare [4]. This means that a whole new age of industrial revolution is just around the corner. During this period, engineers will be able to fully take use of the state of the art technology available, improving lives all around the world and socialising manufacturing in the process (see Social Factories). Several nations, including the United States, Japan, and the European Union, are now working to usher in the human-centered period described above, also known as Industry 5.0 (and by extension, Society 5.0). It's important to note that the technological evolution known as I4.0 is still in progress, and that Society 5.0 (which includes Industry 5.0) is still in the planning stages; this has led to the widespread belief that the latter will not be recognised as a genuine industrial revolution in its own right. This is a question that hasn't been fully answered, but it is one of the many important results of the current study.

THE FIFTH INDUSTRIAL REVOLUTION

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Many business innovators and technical pioneers are already looking forward to Industry 5.0 (I5.0), which will incorporate autonomous production with human intelligence and AI as a backbone technology, in and on the loop (see Figure 1). The fast expansion of the Internet and Internet-related technologies is expected to raise the number of social media users (4.59 billion in 2022) to 5.85 billion by 2027 [6].

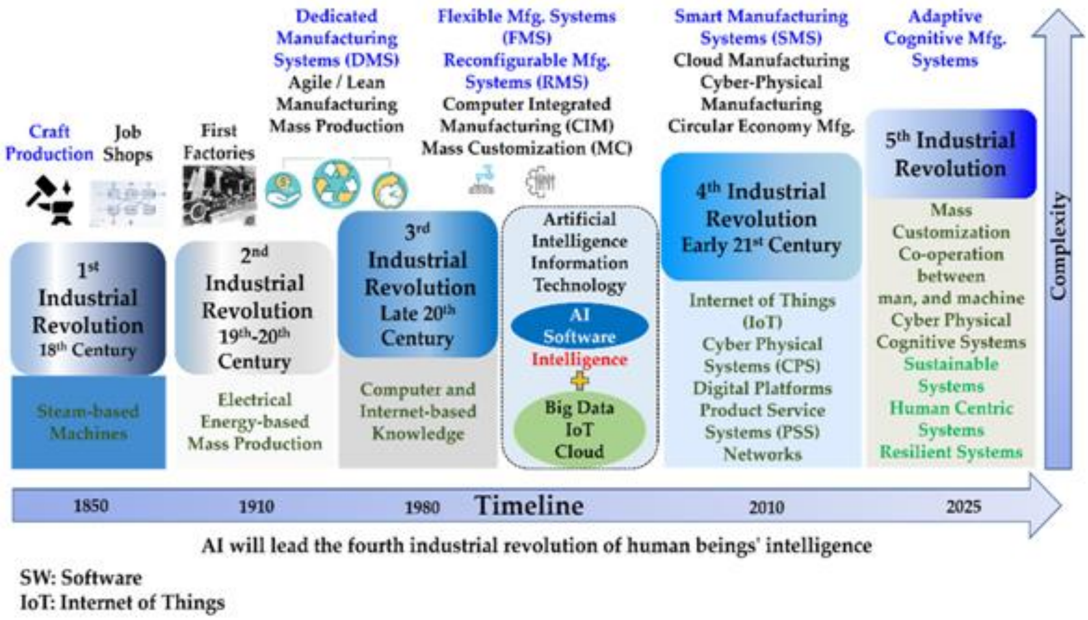

Figure 1. Industrial Revolutions with key milestones and significance of AI towards human beings' intelligence (derived from [7,8]).

Society 5.0

I5.0 [9] has steadily acquired greater attention over the last several years as a human-centric design approach that seeks to overcome the issues revealed by Industry 4.0 by having people and cobots work together in a shared working space. Additionally, a similar concept called Society 5.0 (S5.0) [10] comes into view in these years to solve the problems in current society; it is a futuristic super-smart society in which everyone can enjoy high-quality and comfortable lives through the fusion of cyberspace and physical space by fully utilising ICT (Information and Communication Technology). Made in China 2025 and Industry 4.0 (I4.0) are two examples of similar socio-technical goals that inspired the Japanese government to create this one. Around a similar vein, I5.0 is intrinsically linked to S5.0; both are expected to occur in 2030 [10], when AI has been taught to reason and drive organisational activities autonomously. It is expected that the CPS established in I4.0 [11] will continue to facilitate change in the ways in which humans interact with machines in Society 5.0. Positive attitudes toward technology are crucial for society progress in all areas (including but not limited to learning, healthcare,

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democracy, and the economy) [12]. But this also begs the question of whether artificial intelligence will have a detrimental influence on human society (such as job loss, ethical and practical concerns surrounding the transfer of responsibility from humans to machines, social control, and algorithmic blunders [13].

THESIS STATEMENT AND STUDY QUESTIONS

Though Industry 5.0 (I5.0) and Society 5.0 (S5.0) are both developing themes that have been explored at a high level so far, there is not enough material accessible online that particularly addresses both of these topics at the same time. This paper's contributions to the field and its overarching goal are therefore distilled into the following:

Offering the first iteration of the I5.0 and S5.0 specifications.

Edge computing (EC), digital twins (DT), collaborative robots (CR), Internet of Everything (IoE), big data and analytics (BD&A), blockchain, product service systems (PSS), the metaverse, and beyond are just some of the technologies that allow and power I5.0 and S5.0.

Industry 5.0's most expected uses are dissected, from supply chain management to intelligent healthcare to cloud manufacturing to manufacturing itself.

Highlighting possible research avenues towards obtaining I5.0 and S5.0.

Consequently, these competing paradigms might be seen as two competing ideals for the future of industry and society. Given the anticipated societal shifts brought on by the rapid development of technology infrastructure in Society 5.0, the following research question has been formulated. Thus, the question "which key technical advancements allow the transition from Society 4.0 and Industry 4.0 to Society 5.0 and Industry 5.0?" emerges as a topic for study. The writers also make an effort to answer the following research questions in the course of this review article:

- When focusing on I5.0 and S5.0, which criterion should be prioritised most to guarantee resilience and social value creation?
- How can I5.0 and S5.0's enabling technologies foster productive human-machine partnerships?
- The third question asks whether Industry 5.0 and Society 5.0 can be used as a framework to help businesses and new social requirements coexist.

Documentation and Organizing

The remainder of the paper is organised in the following manner: In Section 2, the methodology for the literature study is provided and addressed. This is followed by a discussion of the

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definitions that are most often used for Industry 5.0 and Society 5.0. Following that, in Section 3, the function of Industry 5.0 inside the framework of Society 5.0 is dissected and examined. After that comes Section 4, which delves into the investigation of the Factories of the Future. In Section 5, a brief discussion is offered after the findings of the literature review that were reported in the earlier parts. In addition, the study is brought to a close in Section 5 of the paper, and future research prospects are considered in light of the presentation of a conceptual framework.

PRESENT-DAY CAPABILITIES

Review Methodology

Scopus, an extensive database, was scoured for the peer-reviewed publications that would serve as the basis for the bibliometric study. However, the same search query was also used to include peer-reviewed papers from other significant databases including Web of Science and Science Direct. Both Google Scholar and Web of Science were used using the same search terms. In July of 2022, a search was made online using the following search query: TITLE-ABS-KEY (Industry 4.0 AND Society 5.0 OR Industry 5.0 AND Society 5.0) AND PUBYEAR > 2015 AND PUBYEAR > 2015. There was a thorough search of journals, conference papers, titles, and publication years. When I did a quick search on "scientific literacy," I got 114 results back. 57 articles in periodicals, 45 papers in conferences, 7 chapters in books, 3 reviews, 1 conference review, and 1 full-length book. Moreover, the bulk of the papers are classified as Computer Science, Engineering, and Social Sciences, all of which are relevant to the issue at hand. However, newspaper stories and reports were not included in the dataset so that the search query may be refined to include only high-quality research papers. Further, a custom Python script was used to analyse the dataset, removing duplicates and tabulating the results. In terms of timeline, the first online conversations and publications about Industry 5.0 and Society 5.0 were made to the research community in 2015, particularly from the Japanese Government. Because of this, looking for information on Industry 5.0 or Society 5.0 after 2015 will not provide any results. However, numerous articles published between 2010 and 2022 featured discussions of Industry 4.0 because of the importance of those breakthroughs to the subsequent Industry 5.0. Although 2022 has not yet ended, more than 15 research papers were included in the article to explain recent breakthroughs in the subject. The purpose of a state-of-the-art study is, therefore, to keep up with the most current developments, to throw light on obstacles and gaps in the literature, and thus include these research works makes that possible.

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After that, the dataset containing the findings was reformatted using a Comma Separated Values, or CSV, file in order to facilitate further processing. The VOS viewer programme was used in an effort to see the data and assess the bibliometric manner in which they were presented. In a more concrete sense, VOS viewer offers the feature of constructing a keyword map based on shared networks. As a result, it is able to generate maps with multiple items, as well as publication maps, nation maps, journal maps based on networks (co-citation), and maps with multiple publications. The users have the ability to change the total amount of keywords that are utilised, as well as delete less relevant keywords. In a nutshell, the capabilities of the VOS viewer programme include the facilitation of data mining, mapping, and the grouping of articles that have been obtained from scientific databases.

The process of topic mapping is an essential part of bibliometric research [14]. Figure 2 depicts all of the topic categories that are relevant to the overarching themes of scientific literacy. Figure 3 is an example of one of the three possible mapping representations that may be shown by VOS viewer in connection with the bibliometric study.

The depth of the investigation into the topic is seen in Figure 3. Figure 3 is a visualisation that, in essence, functions as a heatmap to reveal the patterns that academics are focusing their attention on more often. As a consequence of this, it is possible to draw the conclusion, based on the results of the research that has been done, that there is a great deal of debate regarding IoT, Application, Human, AI, Transformation, Economy, Education, and Sustainable Development.

An process known as clustering was carried out in order to better arrange the important subjects. As shown in Table 1, the mapping of all of the themes resulted in the formation of four (4) clusters after being analysed using the VOS viewer programme.

The clusters make it easier to see the connections between the many subjects, which in turn makes it simpler to analyse the findings. The thickness of the connecting line served as an indicator of the level of significance between a pair of subject areas or keywords. Along with the clusters and lines, the size of the nodes also provided insight into the prevalence of the subject or term. Figure 2 shows that the most common topics or keywords were related to the economy, education, application, artificial intelligence, and conditions. It may be deduced from this that during the years 2015 and 2022, scholars focused the greatest emphasis on these topics. Additionally, nodes or keywords that are not part of a network with other keywords could become new study fields.

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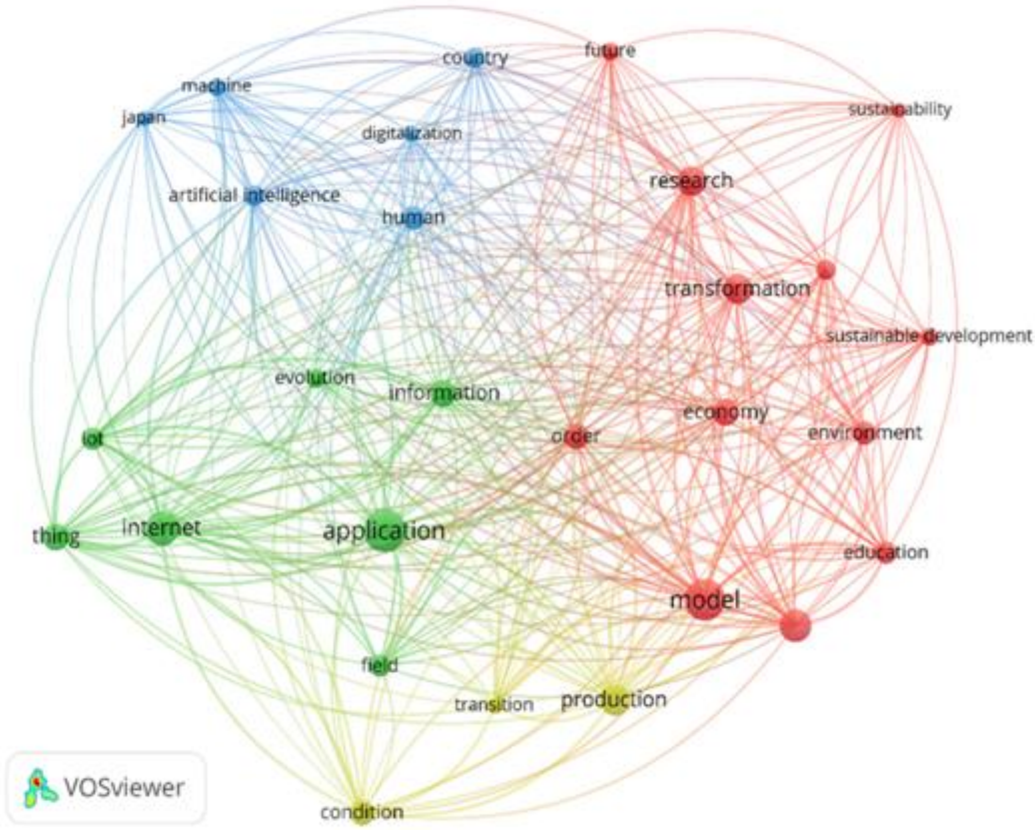

Figure 2. The Network Visualization of Literacy Topic Area.

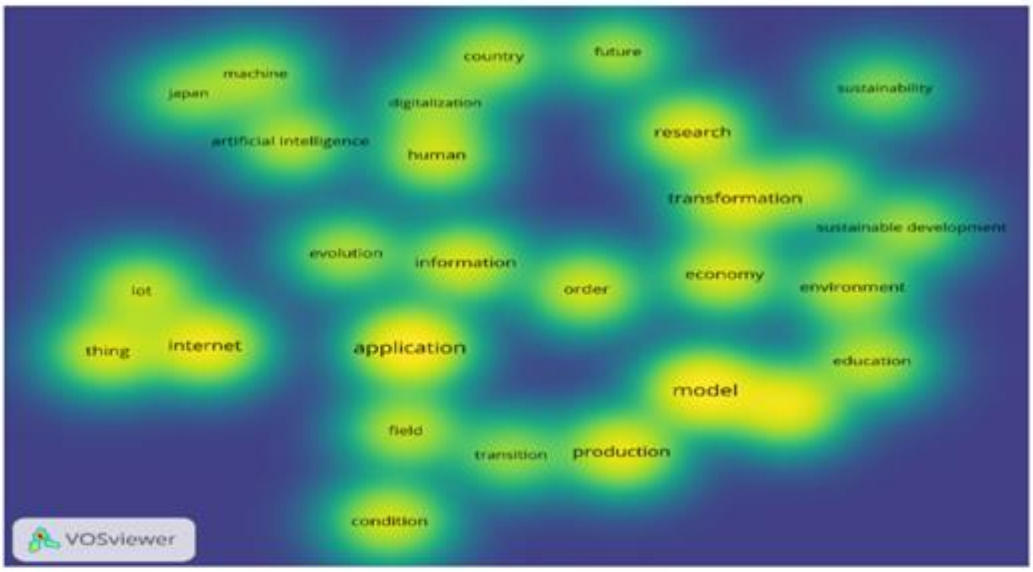

Figure 3. The density visualization of the scientific literacy topic areas.

Consideration of the Algorithm

The authors of the study created the algorithm that was employed, and it is based on the exploitation of APIs (Application Programming Interface) that are supplied by scientific databases (including ScienceDirect, Scopus, and Web of Science). The search algorithm, to be

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more explicit, makes use of three distinct APIs in order to search for publications and produce results depending on the user's inputted search keywords. In order to assemble and format the findings, an XML (eXtensible Markup Language) file is used. This file includes the Title, the Year, the Abstract, and the Keywords.

It was decided to create a recursive approach for excluding results. To be more exact, Information Theory metrics were used to the study of the article's Title. Following that, the Keywords were investigated, and lastly, the Abstract of the document was scrutinised using a third round of analysis. A final XML list was automatically constructed by the devised algorithm after the exclusion recursions were finished. This list was then stored to the local storage medium (for example, a hard drive), allowing users to locate the manuscripts and download them. At this point, it is emphasised that numerous additional query parameters are also enabled in order to improve the users' ability to refine their search queries. This is done in order to make the search process easier overall. It is possible to implement the algorithm as a standalone programme that is designed to run on personal computers. In next advancements, there will be an inclusion of an automatic download of manuscripts that are acceptable. The application that was built is just for use in academic and research settings. The employment of Machine Learning algorithms is the primary benefit of this search algorithm. These algorithms allow researchers to broaden the scope of their literature study and raise the degree of detail when they are searching for information using the algorithm. In addition to the application programming interfaces (APIs), a web scraping module was also built in order to obtain valuable insights from websites that are accessible over the internet. The capacity of the web scraping algorithm to search for and extract information from sources that are not scientific is an additional benefit of the algorithm (e.g., think tanks, leading companies, etc.).

Table 1. Clusters as constructed by VOSviewer Software.

Cluster 1	Cluster 2	Cluster 3	Cluster 4
Economy	Application	Artificial Intelligence	Condition
Education	Evolution	Digitalization	Production
Environment	Internet	Japan	Transition
Future	IoT	Human	
Implementation	Thing	Machine	
Innovation	Field	Country	
Sustainable Development	Information		
Sustainability			
Research			
Transformation			
Order			

Explanations of What "Industry 5.0" Means

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In order to give the necessary background for the discussion of Society 5.0 and its elements that will take place in the next part, the definitions of Industry 5.0 that are most applicable to the topic are supplied in this section.

The first definition is based on the findings of the study conducted by Breque and colleagues (Breque et al., 2012). According to the authors, Industry 5.0 is a forward-thinking idea that looks to the future of industry in the direction of a manufacturing system that prioritises people, is sustainable, and is highly resilient (Breque et al., 2021). I5.0 is fast to act, robust, and respects the constraints of the world while simultaneously cultivating talent, diversity, and empowerment [15]. This is made possible with the use of technologies that are adaptive and flexible.

According to the third definition supplied by [8], human and machine cooperation in the industry leads to greater process efficiency thanks to the use of human ingenuity and the enhancement of automated procedures.

I5.0, as predicted by Friedman and Hendry [17], will reportedly make business professionals, IT specialists, and philosophers prioritise consideration of human issues while introducing novel technology into manufacturing environments.

Socially intelligent factories staffed by cobots are the hallmark of the fifth industrial revolution, or Industry 5.0. The Social Smart Factory [18] utilises enterprise social networks to provide smooth interaction between human and CPPS components.

Taking into account the aforementioned criteria, it is clear that there is a convergence on the principles of human-centricity, system resilience, and sustainability. Differences emerge upon closer inspection of the definitions, with the bulk of definitions including a full age of technology and social advancements associated with Industry 5.0, while the others focusing more on the industrial change.

Terms for Social Organizations, Fifth Edition

In this continuation of the previous section's discussion, we'll look at the most important terms associated with Society 5.0. Figure 4 summarises the major sociological revolutions before delving into the description of Society 5.0. Society has progressed in tandem with the industrial revolution. If we analyse the revolutions that have shaped industry (like we did in Section 1), we can see how they mirror societal changes. Industry 4.0 is a superset of the current state of knowledge and imagination, and so is the notion of Society 5.0.

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Figure 4. Societal evolutions categorized in key aspects.

In response to the challenges facing the Japanese economy [19], the Japanese government first mentioned their vision of a human-centered society, "Society 5.0," in 2015. This society is characterised by a high degree of integration between cyberspace and physical space, which they believe will lead to economic growth and the solution of social problems. An ageing and diminishing labour force, growing global competitiveness demanding infrastructure improvements, natural catastrophes, terrorism, environmental concerns, and a depletion of natural resources are among the most pressing problems our modern civilization faces. From 2017 forward [20], this approach is applied in studies conducted by Granrath on Japan's Society 5.0 and beyond Industry 4.0.

A concept and roadmap for social evolution, Society 5.0 may have a significant influence on existing societal structures on a variety of levels, claims Serpa (in the MDPI encyclopaedia) [21]. Adopting the Smart Society paradigm to enhance human well-being and ensure environmental sustainability will be crucial to progress.

Society 5.0 is defined by Deguchi et al. in their book [22] as a highly intelligent society based on the creation, processing, sharing of data and more precisely knowledge via the link of the physical world with the internet.

Rojas et al. [23] in the same year characterise Society 5.0 as a "Super intelligent Society," using the technical gains made during Industry 4.0 for the greater benefit of society and environmental sustainability, echoing the term used by the Japanese government.

Traditional societies will give way to Industry 4.0 and Society 4.0 in the near future.

The third industrial revolution was fuelled by the invention of the transistor as well as the microprocessor (1960). The acceleration of technological progress in areas such as computing

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and communications, as well as the beginning of process automation, was made feasible by the aforementioned advancements. As a consequence of this, society began the process of transitioning from producing things and generating a profit to becoming a post-industrial society that is built on the creation of information and the growth of service sectors. The post-industrial or information society, which places an emphasis on the organisation of knowledge and functions as a social control mechanism, hence directing innovation and development, went through a transition in the 1980s as a direct result of the introduction of digitalization [24]. As a direct consequence of the growth of the Internet, a global information society has emerged with the objective of delivering better education, networking opportunities, and assistance for businesses. Because the contemporary information societies are built on a capitalist economy, it is equally vital to stress the institutional and cultural variety of information systems (such as the distinctions between various countries and nations). In addition, the contemporary information society is founded on the most cutting-edge technical advancements for the processing of data and the generation of new information. The advent of the information era has placed a significant focus on different phases of data collection and processing. Figure 5 depicts how the conventional society is undergoing a fast structural transformation as a direct consequence of the Fourth Industrial Revolution. An sophisticated artificial intelligence system is going to be utilised to evaluate and process massive volumes of data that are received by devices and sensors that are spread out all over the physical world. After that, the analysis will have a considerable influence on the activities that take place in physical space, both involving humans and machines. Cyberspace and the physical world are getting more intertwined with one another. As a consequence of this, educational institutions need to place an emphasis on the growth of talents, the formation of collaborative partnerships, and the advancement of present careers [25]. As a result, it is important to emphasise that society is a particular kind of social structure in which the accumulation, processing, and transmission of information become the primary sources of power and production.

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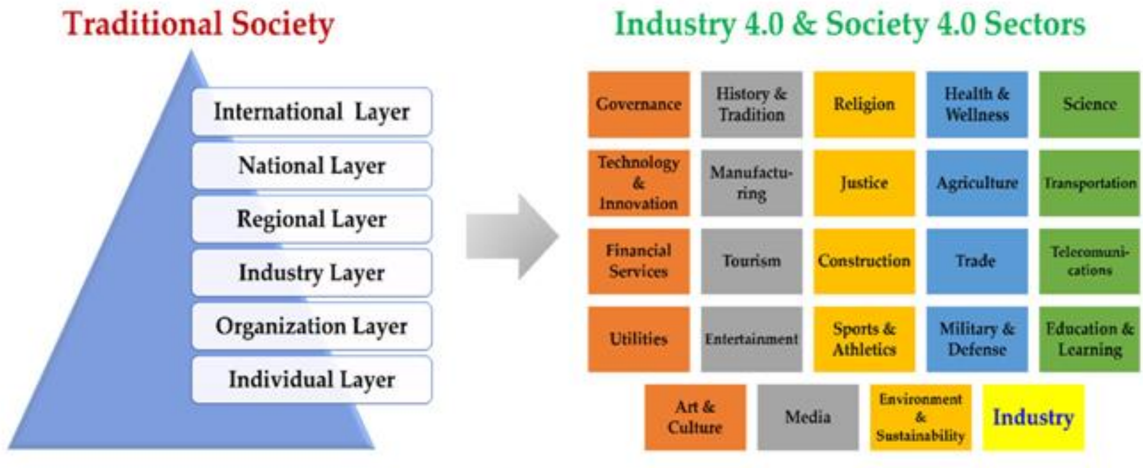

Figure 5. From Traditional Society to Society 4.0.

Concept of a Sustainable Society Version 5.0

While Japan was the inspiration for the Society 5.0 concept, any country may benefit from its sustainable development philosophy. That's why, while implementing the idea, it's crucial to focus on its parts that pertain to the expansion of industry. Industry 4.0 is a production-centric approach that has been widely adopted in Europe for quite some time. In contrast, the focus of Society 5.0 is on interpersonal relationships. To that purpose, we may adopt just those features of the Japanese approach that are geared at enhancing societal activities unrelated to manufacturing [26].

Society 5.0 seeks to harness the power of the digital transition not just to foster economic expansion, but also to address societal issues and enable people to live in harmony with environment. It will help in accomplishing the UN's Sustainable Development Goals (SDGs) [27]. Therefore, in Figure 6, we see a detailed social ideal called "Society 5.0 for SDGs."

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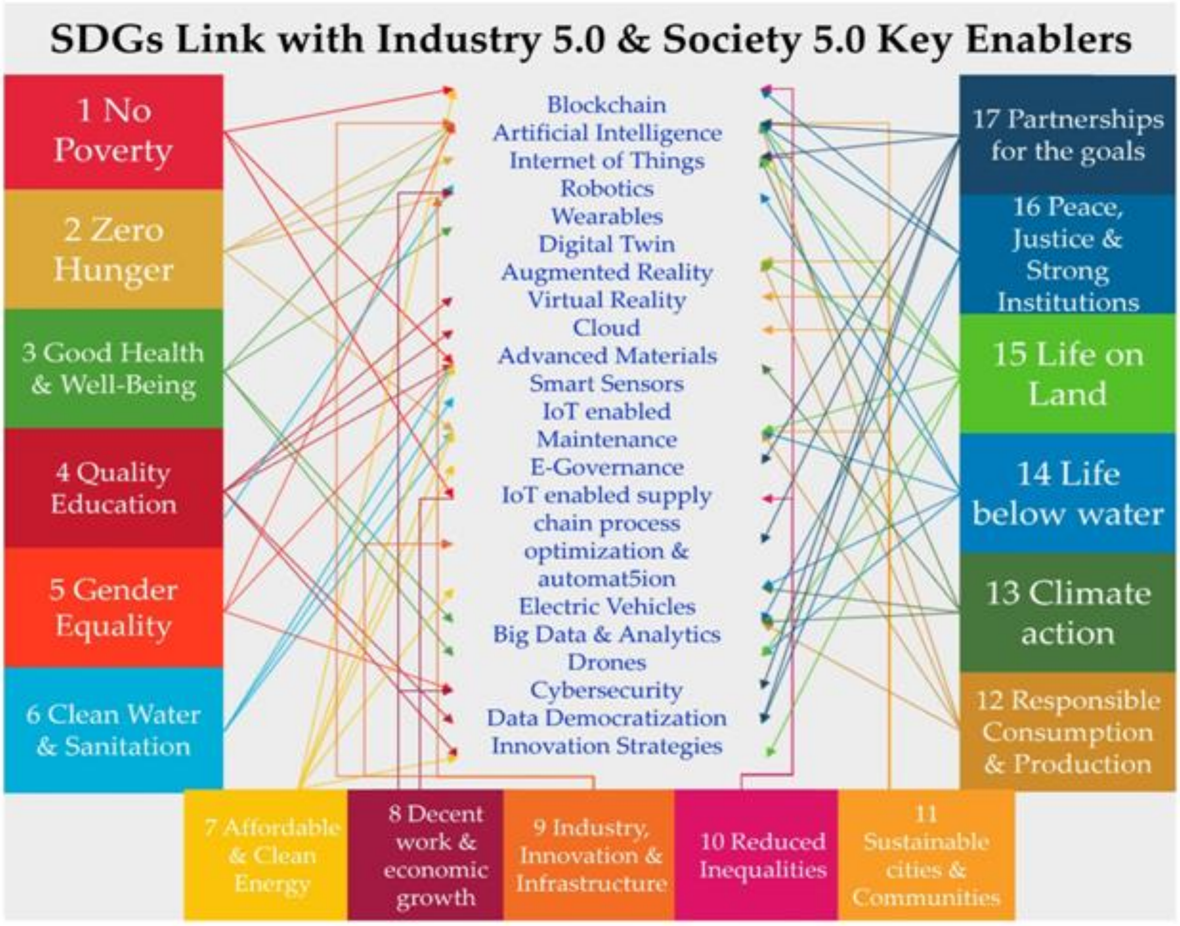

Figure 6. Society 5.0 for Sustainable Development Goals.

Going ahead, the Keidanren will make the necessary strides in developing and implementing this notion, which will have far-reaching effects on the Japanese economy and society [28]. Social mores and commercial practises will undergo radical shifts in the Society 5.0. Close cooperation across borders and sectors, in addition to the change of current industries, will allow people to pursue a wide range of lifestyles. By addressing societal problems, S5.0 hopes to bring about a world where people are free to seek their own pleasure and way of life while simultaneously contributing to environmentally friendly, sustainable growth. Consistent with the SDGs, which were set by the UN to solve global concerns and promote sustainable societies, this helps make the world a better place for everyone. Although necessary for achieving several of the SDGs, S5.0 is not enough on its own. The development of S5.0 will allow for the direct achievement of certain goals, while also facilitating the development of other solutions that will help advance other goals. Since S5.0 promotes creative problem-solving from a range of viewpoints and backs up these answers with digital transformation, it will be possible to achieve the SDGs. This section provides the blueprint for sector-specific

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changes, including how they would help accomplish the Sustainable Development Goals (SDGs), that will be necessary to reach S5.0.

Innovating in the Digital Age

Society 5.0 (Creative Society) will be a society that we develop ourselves by integrating Digital Transformation (DX) with the imagination and creativity of a broad variety of individuals to create values and discover answers to issues. Using DX to build a better future civilization is a fantastic concept. The ongoing DX, which refers to the fundamental transformation of society as a result of advances in digital technology and data use, is driving the creation of S5.0. This DX has resulted in profound changes to people's daily lives, government operations, the structure of the economy, and the job market.

When data gathering, transmission, storage, and analysis can be done on a massive scale at a reasonable cost, it sparks a variety of innovations in manufacturing [29]. By highlighting issues and providing possible solutions, data is invaluable. Global instantaneous sharing of such information and insights is key to solving management and societal challenges. Data eXchange (DX) employs data-based technologies such as the Internet of Things (IoT), artificial intelligence (AI), 5G, robots, and blockchains to effect significant societal shifts [30,31].

DX's impact extends beyond technical advancements. Because of this, societal standards are changing on a fundamental basis in lower-class societies. The benefits of "kaizen," automation, better productivity, and digital technology-based optimization are just the beginning of what DX has to offer. DX is reform that seeks to develop new values in reaction to large societal changes, sometimes at the price of old values. As a result, it may be emphasised that DX is a change that affects the very fabric of society and industry, rather than only requiring the adaptation of new technologies. Thus, companies should consciously and proactively make DX their top management priority [32]. Within the context of the Keidanren proposal, DX is defined as follows:

"Fundamental and revolutionary changes in society, industry, and life as a result of advances *in the use of digital technology and data; and radical changes implemented by* industries, *organizations, and individuals toward such transformation."*

The Social Fabric, Fifth Edition

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Despite ushering in a new stage of society, digital transformation should be used to build a world where individuals are free to seek their own unique versions of success and fulfilment in the digital era. There are several facets to the new Society 5.0, which was first defined as a "super smart society" in the 5th Science and Technology Basic Plan [33,34]. According to Section 2.6, "advanced capabilities" are now available to the general public as a result of digital transformation. Aspiring and creative individuals can engage in endeavours with far-reaching consequences for the world at large.

Society 5.0 will require vivid imaginations in order to identify the wide range of societal demands and issues and to imagine possible scenarios for resolving them, as well as ingenuity in order to develop solutions that make use of digital technology and data. Problems can be solved and value can be created more quickly and easily when digital transformation is combined with the imagination and creativity of many different individuals.

Furthermore, Society 5.0 will be a Creative Society where digital change interacts with the imagination and creativity of different individuals to address social concerns and create new value. Thus, as shown in Figure 7, in Society 5.0, humans will employ their creativity to create methods to live in harmony with environment, technology, and each other in order to promote sustainable development.

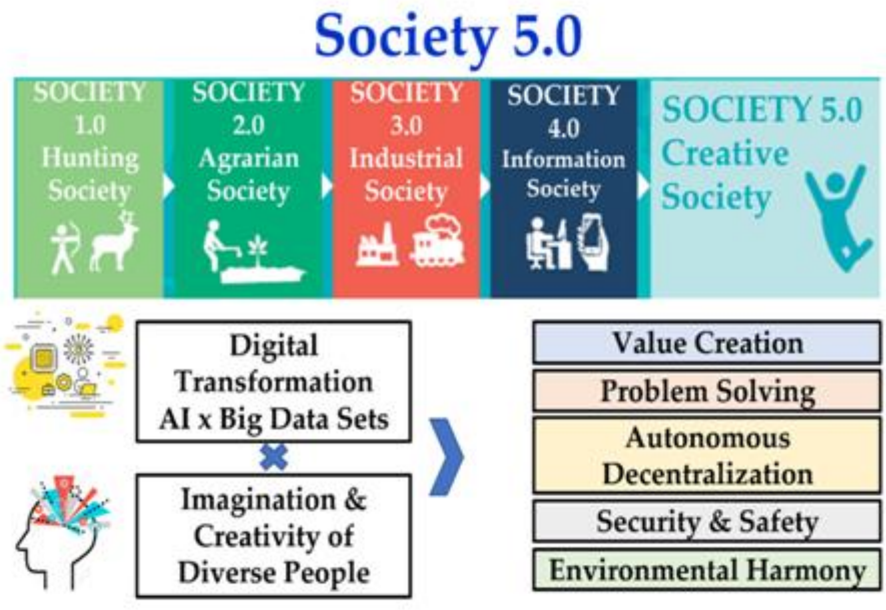

Figure 7. Evolution of society—Co-creating the future (adapted from [35]).

Progressing from the Fourth Industrial Revolution to the Fifth Industrial Revolution

Figure 8 depicts the differences between Society 4.0 and Society 5.0 in terms of value creation and issue resolution, variety, decentralisation, resilience, sustainability, and environmental

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harmony. Society 5.0 is best understood as an Industry 4.0 setting with a focus on people. Society 5.0, a term coined by the Japanese Cabinet Office, is defined as "a human-centered society that balances economic growth with the settlement of social issues through a system that highly combines internet and physical space." We can utilise data and technology to encourage a culture where individuals from all walks of life can thrive [35]. People in Society 5.0 will also be able to follow a wide range of lives and ideals thanks to the removal of barriers that have prevented them from doing so in prior iterations of the society, up until Society 4.0. To be more precise, people will be freed from the pressure to maximise productivity. Instead, we shall be concerned with the needs of specific people, as well as the resolution of specific issues, and the generation of tangible value. People won't have to worry about being treated differently because of who they are or where they're from, or what they believe in the workplace. Additionally, everyone will be able to discover chances to engage whenever and wherever they choose, eliminating the inequalities brought on by the centralization of wealth and knowledge. By strengthening safety nets for unemployment and poverty, one of the goals of the shift from Society 4.0 to Society 5.0 is to allow people to live without fear of terrorism, natural disasters, and cyberattacks. Finally, the purpose of the 2019 World Economic Forum Annual Meeting is to build a society where anybody, at any time and from any location, can generate value without fear or interference from authority, in complete harmony with the natural world [36].

Goals for Sustainable Development and the Human Condition 5.0

As a result of S5.0, many things in life and business will shift. The SDGs will benefit from this social revolution since it seeks to find solutions to social problems by working in tandem with nature. Table 2 summarises the SDGs to which each numbered reference below pertains.

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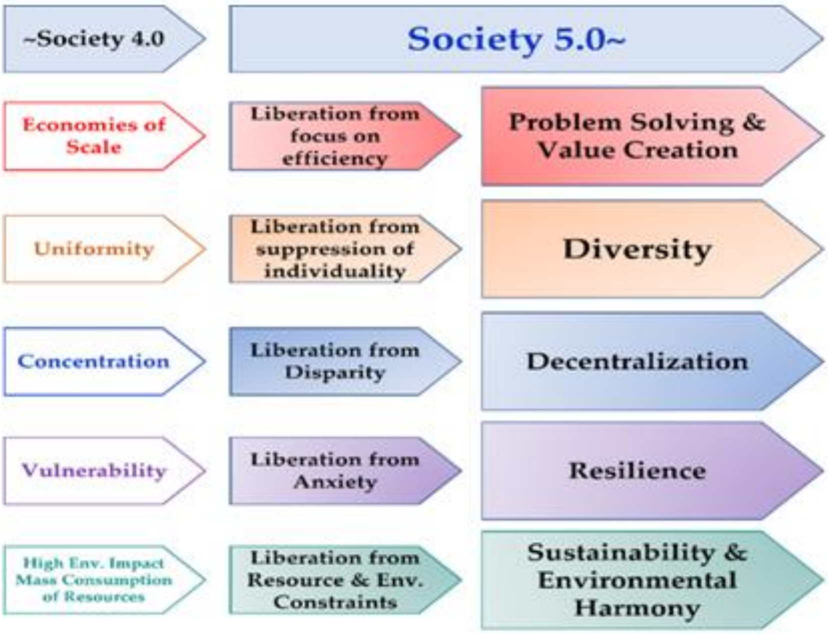

Figure 8. Changes from Society 4.0 to 5.0.

Table 2. The 17 sustainable development goals (SDGs) to transform our world, derived from [37].

The 17 Sustainable Development Goals (SDGs)	
GOAL 1	No Poverty
GOAL 2	Zero Hunger
GOAL 3	Good Health and Well-being
GOAL 4	Quality Education
GOAL 5	Gender Equality
GOAL 6	Clean Water and Sanitation
GOAL 7	Affordable and Clean Energy
GOAL 8	Decent Work and Economic Growth
GOAL 9	Industry, Innovation, and Infrastructure
GOAL 10	Reduced Inequality
GOAL 11	Sustainable Cities and Communities
GOAL 12	Responsible Consumption and Production
GOAL 13	Climate Action
GOAL 14	Life Below Water
GOAL 15	Life on Land
GOAL 16	Peace and Justice Strong Institutions
GOAL 17	Partnerships to achieve the Goal

The following is a synopsis of the individual sector's proposed changes and roadmaps:

Goals 3, 4, 5, 6, 8, 11, 12, and 13 of the Sustainable Development Agenda for Cities and Regions

Many different types of lifestyles may be supported while having much less negative impacts on the environment if autonomous technologies like automatic driving and sharing economies are encouraged. Sustainable, decentralised communities will be developed in suburbs and rural areas to create autonomous, prosperous regions where people live in harmony with nature by utilising the unique qualities of their respective regions; this will occur while continuing to work to improve the competitiveness of large cities. High-quality medical treatment and

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academic programmes will be accessible from any location. Independent, decentralised social infrastructure technologies, such as off-grid energy, will be utilised to build a strong, long-lasting social system while reducing costs for its users.

Seniors who live in locations without a reliable public transit system will have access to autonomous vehicles, allowing them to go about their everyday lives without worrying about how they will get to and from places like grocery stores and medical appointments. It is possible to live to high standards and in comfort even in regions with poor infrastructure.

Energy-related Sustainable Development Goals (#7, #9, #13)

Anywhere, from high-tech urban centres to decentralised neighbourhoods, people will be able to live sustainably if they have access to data that can be utilised to design efficient energy networks. Decentralized microgrids will have demand-side controls, power storage, and distributed renewable energy sources that are all synchronised with local needs. To avoid relying on utility companies, people can use alternative energy sources called "off-grid" systems. Most of the world's population, if not all of it, will have access to cheap, reliable energy, and many other businesses will follow suit by employing decentralised systems. This will guarantee that the vast majority of people on Earth may have fulfilling, varied, and long-term lives.

Third, Eleventh, and Thirteenth Sustainable Development Goals: Disaster Prevention and Mitigation

The frequency and severity of natural catastrophes are rising worldwide, calling for swift action and greater resilience. Disaster information collaboration tools will be developed to allow rapid responses by collecting data on damage and rescue supplies from evacuation centres, IoT devices, and social media and sharing it across geographies and organisational barriers in the public and commercial sectors. Daily upkeep and effective safeguards against infrastructure deterioration will be accomplished with the help of digital technology. Emergency situations don't have to interrupt water service, thanks to preventative measures and rapid repairs to water and sewage systems. We will be encouraging robust infrastructure built on decentralised energy systems.

Health Care for All People

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To ensure that everyone receives the care they need, when they need it, we will leverage emerging technologies like the digitization of unique physical traits and behaviours and developments in biotechnological research into the processes of life. As opposed to the standardisation of care provided by conventional medicine for the typical patient or symptom, the personalised care provided by innovative methods will focus on disease prevention.

Access to high-quality healthcare services will be made possible from anywhere by promoting next-generation high-speed communication networks, artificial intelligence-based medical, agricultural, and nutritional wellness support services, telemedicine, and the development of systems for people to actively use and manage their own life-stage data. This will allow everyone to enjoy long, healthy lives. Remote seniors, for example, will have access to health monitoring via telemedicine; in the case of an emergency, they will be evacuated to a hospital most suited to their needs, as decided by AI. These technology, operational knowledge, and systems have the potential to enhance healthcare throughout the world if they are adopted in underserved areas of poor countries.

Sub-Goals 2, 12, 14, and 15 Concern Agriculture and Food

Agriculture and food production will be revolutionised into exciting new fields where individuals may use their own initiative and ingenuity. AI-enabled remote monitoring and control, robotic farming, and self-driving drones for on-site agricul- tural labour will all be put to good use. Workweeks will be cut in half, efficiency will increase by leaps and bounds, and output will increase exponentially as a result of the combined efforts of many parties, including private enterprises, young people, and agritech startups. Strategies to increase biodiversity and lessen environmental damage will be promoted in an effort to preserve the vast marine and terrestrial ecosystems. It is planned to rapidly incorporate customer feedback into food manufacturing. Sharing real-time stock and sales data is made feasible by integrating production, logistics, and export data, and food waste is minimised via better planning of delivery times, quantities, and routes. Information about the manufacturing process, product specifications, and customer feedback will all be freely available to customers.

SDGs 11 and 12 relate to logistics

Logistics contribute to economic growth by easing the transportation of commodities, and they form an essential part of the social infrastructure upon which our everyday lives and commercial economies depend. In Society 5.0, logistics will become even more complicated

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and diverse due to the fast growth of e-commerce and the globalisation of supply chains, as well as the widespread use of cutting-edge technologies that will revolutionise logistics. Internet of Things (IoT) technology like Radio Frequency Identification (RFID), for example, will be used to link freight and transportation systems to networks, allowing for real-time logistical tracking and management.

Goals 5, 8, and 9 in Manufacturing and Services Sectors

As AI enables the sharing of skills, manufacturing and service provision will have access to cutting-edge new resources. It has always taken a large investment of time and resources to analyse data and turn it into valuable goods and services. Thanks to digitization, these abilities will be shared and made available as AI modules and services. If you combine them, you can crank out better goods and services much more quickly. Business models will be based on services, not physical products. In the age of digitization, manufacturing and services will not be a continuation of their 20th century counterparts. More individuals will be able to take part in production and service delivery if DXs produce several types of value.

Budgeting: Goals 1, 5, 8, and 9

Individuals and small enterprises are able to supply a wide range of manufactured goods and service options because of the evolution of financial services. DX will increase the availability of a wide range of financial services, including asset creation, financing, settlement, and insurance. Because of cheap, useful, rapid, secure, and varying means of settlement, individuals will be able to live wherever without using currency. New service creation will be simplified by apps that bridge existing services with smart contracts. Financing, asset development, insurance, settlement, and transfer will become easier with the use of digital gadgets and technology, leading to more economic independence, improved living standards, and greater income equality in developing nations.

Cryptocurrencies and token economies based on blockchain technology and other developments will produce new methods of exchanging wealth and make previously unattainable lifestyles viable. Establishing safe, smart, and trackable global contracts and settlement systems would pave the way for individuals of all backgrounds to increase their manufacturing and service offerings on a worldwide scale.

Goals 1, 3, 4, 10, and 16 for Public Services

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Public services will also undergo major transformation to accommodate the aforementioned populations and economic sectors. The first step for governments at all levels will be to revamp their digital infrastructure. By digitising numerous processes and rapidly disseminating data across diverse players, they will be able to provide more creative public services. For instance, governmental authorities may better meet the needs of their citizens by doing precise demographic and other data analysis to forecast the need for nurseries, schools, hospitals, and nursing homes. When governments put in place sufficient safety nets, every citizen may face a wide range of security threats.

The 5.0 Era and Industry

The industries studied thus far have been classified according to their nature and the goods they manufacture. However, in the next part, they are sorted according to the benefits they provide to the customer and the issues they fix. The current industrial structure, known as 5C Architecture [38], is a pyramid with huge firms at the top. This will be replaced with a flat co-creation framework. Table 3 shows the industrial shift from Society 4.0 to Society 5.0 and beyond.

Table 3. Industrial Focus of Societies.

	Society 1.0 to Society 4.0	Society 5.0 and Thereafter
Industrial Focus	Product and Business Types	Values realized and issues solved
Areas of application	Electricity, mobility, infrastructure, construction, medical equipment, logistics, and financial services	Comfortable mobility, environmentally friendly energy, and realization of health
Common Goal	Transition to an autonomous, decentralized co-creation framework where businesses construct an industrial structure based on the values of the consumers and combine technologies and channels in their areas of specialization to realize these values	

Creation as a Group Effort in the Age of Society 5.0

When we talk about co-creation, we're talking about a new kind of cooperation that goes beyond traditional commercial or corporate partnerships by focusing on the needs of consumers and finding innovative solutions to social problems. It is predicated on the introduction of novel business models and ecosystems, wherein diverse organisations generate revenue via the coordinated application of several techniques that play to their respective strengths while compensating for their shortcomings.

Methods for Collaborative Creation

The following is not an exhaustive list of the ways in which companies might collaborate to generate new business prospects. The success of co-creation depends on the establishment of appropriate governance frameworks that encourage engagement from a wide range of

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stakeholders, the definition of clear and actionable consumer objectives and values, and the facilitation of multi-level communication.

The first is collaborative production of goods and services.

Second, sharing data for collaborative production.

Thirdly, utilising human capital for joint production.

Management

Managers in Society 5.0 will need to have the following set of competencies.

1. having an awareness of DX and a strong desire to put it into practise.
2. a company with a well-defined goal and a strong leadership role in the field of co-creation.
3. familiarity with cutting-edge industries and technology.
4. Refocusing.
5. Quick thinking and responsiveness

Human Resources Novel ideas, ideation, and the development and execution of business plans are just some of the many facets of DX promotion that need for specialised individuals.

Organization

The ability to develop new ideas and allow change via variety is the most crucial aspect of any organization's culture.

Technology

In order to keep offering systems and services to clients while also becoming DX-ready, it is essential to rapidly integrate digital technology. These call for consistent DX application while keeping tabs on emerging innovation.

Co-Creation of Data

In order to move forward with co-creation, it is crucial to establish a shared infrastructure based on a connected yet autonomous and decentralised architecture. Next, in order to eliminate issues hindering data sharing, it is also vital to specify quality requirements for transmitted and connected data.

Industries 5.0's Key Enabling Technologies

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Industry 5.0 is the idea of an industry that is cutting-edge, resilient, socially-centered, and competitive, all while being conscious of environmental impacts. It raises a plethora of new issues in the realms of engineering, socioeconomics, regulation, and leadership. The topic of Industry 5.0 was explored at two online workshops conducted on July 2 and 9, 2020, with participants from from funding agencies and RTOs all around Europe. The goal was to have a conversation about the technology that would make this possible, the challenges that may arise, and to get people's thoughts on the concept as a whole. The group mostly agreed that technological innovation should be more mindful of societal and ecological concerns. Participants also agreed that a comprehensive approach was required to handle the complexity of the difficulties rather than relying exclusively on individual technologies [39].

Human-centric solutions and human-machine interaction technologies that integrate and combine the strengths of humans and machines are among the Key Enabling Technologies (KET) that are facilitating the shift from Industry 4.0 to the notion of Industry 5.0.

Materials that can be recycled but also contain sensors and have enhanced properties thanks to bio-inspired technology and intelligent materials.

Whole-system modelling and simulation using real-time digital twins.

Technologies for managing system and data interoperability that use cryptographically-protected data analysis, transport, and storage.

Some examples of AI capabilities include the capacity to learn and adapt, as well as the generation of actionable insights from data gathered about complex, dynamic systems.

Due to its high power consumption, the KET necessitates the development of autonomous systems that are both efficient and dependable in terms of their use of energy.

Many recent technological developments, such as Edge Computing (EC), Digital Twins (DT), the Internet of Everything (IoE), Big Data Analytics (BDA), Cobots, 5G, and blockchain, can help businesses improve output and speed up the delivery of individualised goods thanks to the combination of cognitive abilities and innovation. Industry 5.0, made possible by these enablers, is a cutting-edge manufacturing paradigm that prioritises communication between robots and humans. Technology enablers for Industry 5.0 are discussed.

Computing at the network's periphery (also known as "Edge Computing") enables data processing. The advent of EC is due to the proliferation of IoT devices and services as well as the maturation of the cloud computing industry. In addition, EC can meet needs for low latency prices, limited battery life, quickly satisfying response times, and secure and private data storage [41]. Further, it guarantees that applications continue to function well even when

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deployed to far-flung sites by cutting down on communication expenses. Furthermore, EC may process data without transferring it to a public cloud, reducing worries about data loss during crucial Industry 5.0 events [42].

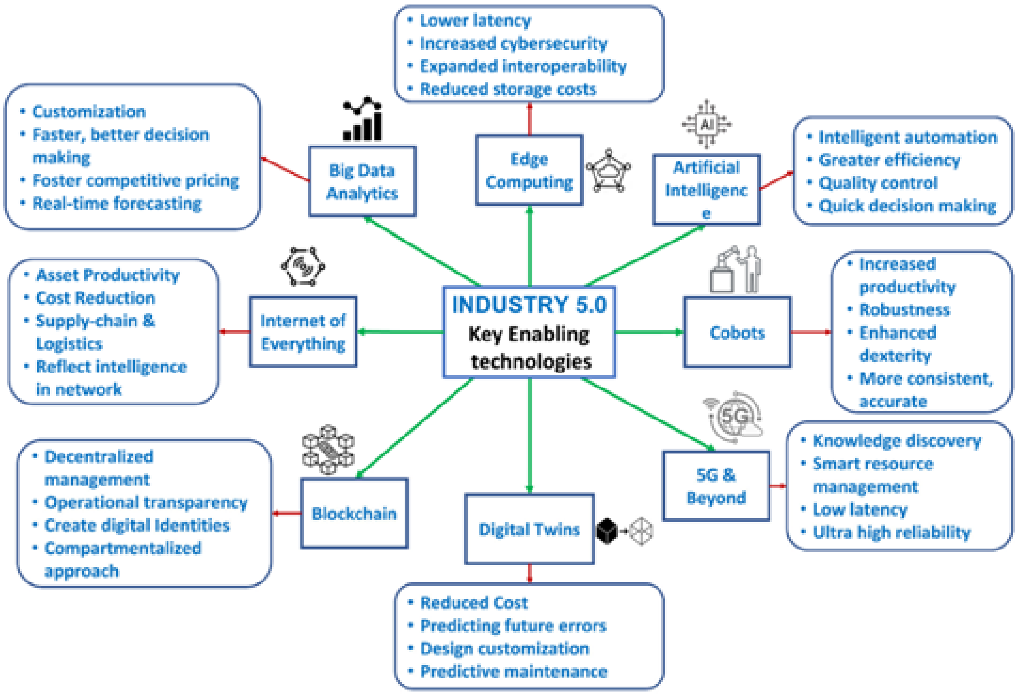

Figure 11. Key Enabling Technologies in the transition from Industry 4.0 to Industry 5.0 (derived from [40]).

Through Internet of Things (IoT) gadgets, data from real-world items may be sent to their digital twins for the sake of simulation. As a result of DT's digital mapping of real-time objects and systems, problems may be analysed, monitored, and averted before they ever occur in the physical world. Reduced upkeep costs and improved system performance [43,44] are all thanks to the rapid advancements in AI, ML, and BDA used in DT. In Industry 5.0, DT is used to personalise products in a way that benefits the end user.

The term "Internet of Everything" (IoE) refers to the interconnected web of devices, people, places, and things. The Internet of Everything (IoE) has the potential to greatly benefit the development of Industry 5.0. New features, enhanced usability, and widespread economic benefits are all possibilities because to the widespread implementation of a few select apps. The Internet of Everything (IoE) plays a crucial part in Industry 5.0 by enhancing consumer loyalty and happiness through the provision of individualised services by means of collected data [45,46].

Big Data Analytics (BDA) will have a major effect on the fifth industrial revolution. Most companies in the 5.0 Industrial Revolution may benefit from BDA by using it to analyse

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customer preferences and make informed decisions about product pricing, manufacturing efficiency, and other expenses [47]. Understanding user behaviour, social interactions, and human behaviour standards is a substantial obstacle. As a result of real-time analytical shared data with smart systems and data centres, manufacturers may create and handle massive amounts of data. In order to achieve continuous process improvement in Industry 5.0, it is sometimes necessary to collect extensive data on the whole production process [48].

New developments in automation and robotics have made cobots (collaborative robots) increasingly important in the workplace. As a result of the tremendously rapid developments in AI and smart technology, it is clear that all computational devices have gotten more intelligent, and a new technology known as cobots has been created. We call robots that are intended to work in tandem with humans "collaborative robots."

Moreover, the teamwork involved in this process makes automating human talents easier for individuals and smaller enterprises than ever before [49]. While they can't compare to humans in terms of critical thinking, robots excel in high-volume product manufacture and can tolerate far more abuse than people. Robots might make it difficult to make things with specific features or details. Therefore, it is crucial to manage interpersonal connections within industrial procedures. Cobots in Industry 5.0 are able to do their intended tasks, allowing for the rapid and precise delivery of products with extensive customization options to clients [50].

Future 5G and 6G technologies may considerably boost the value of Industry 5.0 services. Very dense networks of hundreds or millions of sensors, hardware components, and robots present significant challenges when constructing radio infrastructure. The exponential expansion of smart infrastructure and prospective applications will result in bandwidth demands that existing networks cannot support (such as 4G and 5G networks). Lower latency, support for high-quality services, broad IoT infrastructure, and integrated AI capabilities are just some of the ways in which 5G and beyond will pave the way for the Industry 5.0 revolution [30,51].

Blockchain: This distributed ledger system has the potential to greatly improve the 5th Industrial Revolution. The Industry 5.0 paradigm poses the difficulty of centralised administration of a large number of heterogeneous connected devices. Distributed ledger technology, or blockchain, may be utilised to create new kinds of distributed and decentralised administration and learning environments [52,53]. Thanks to blockchain technology, we can now communicate securely with one other, creating a shared ledger that cannot be altered. The immutable ledger also facilitates operational accountability and transparency for pivotal events in Industry 5.0 deployments [54].

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EXtended Reality (XR) and Other Enabling Technologies: The futuristic XR technology may be utilised in a wide variety of settings. Improved human-machine interactions are one of the many benefits of XR's fusion of the real and virtual worlds. The word "XR" [55] encompasses the many forms of immersive technology such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). There will be many ways in which XR technology facilitate Industry 5.0 applications. Remote assistance [56], monitoring of production lines [57], remote healthcare [58], health education [59] and training [60], indoor and localised outdoor navigation [61], training of drivers and pilots [62], maintenance [63], and education and training for operating drones and unmanned aerial vehicles [64] are all examples of applications that use XR technologies related to Industry 5.0. Zero-touch networking, edge computing, highly competent devices, enhanced communication technologies, and high- precision calculation capabilities will be essential for XR technology to develop toward Industry 5.0 applications.

Technology Requirements for Highly Customized Production in the Industry 5.0 Era To begin mass personalisation, it is essential to use a more flexible supply chain and production method [66]. These processes will also require human involvement, such as feedback from the production crew and the clients, in order to maintain a bespoke feel. Mass personalization's long-term success will also be heavily dependent on how cheaply it can be produced. Because of this, the writers in [64] have developed a technological road map for Industry 5.0 projects, which includes the following:

Priorities: 1. A system for managing and governing data.

Methods of modelling and simulating multi-scale dynamic systems.

Third, self-driving intelligent machines.

Fourth, advanced forms of human-machine interaction and cognitive systems.

Insert number five: additive production.

Sixth, a personal touch from another person.

Compelling Abilities for the Corporate and Social World 5.0

There are various facets to the AI-driven industrial revolution, and one of them is the enhancement of machinery and manufacturing processes. It's much more crucial to put money into people who can help make those new projects successful in the long run. Three-sixths of firms see a lack of technical skills as a major impediment to getting the most out of their smart factory investments [67]. Additionally, 57% of industry executives state that they lack AI

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ability, which is crucial for all of the autonomous and intelligent solutions that will take over the 3D activities. Table 5 details the top five most in-demand abilities of now and tomorrow.

Table 5. Top five critical skills for today and the future [25].

Skills of Today	Skills of the Future
Basics of modern programming or software engineering	Deep understanding of modern programming or software engineering techniques
Manufacturing skills	Digital dexterity, or the ability to leverage existing and emerging technologies for practical business outcomes
Great communication skills	Data science
Innovation skills (e.g., brainstorming, design thinking)	Connectivity
Traditional IT skills	Cybersecurity Manufacturing Skills

ANALYSIS AND PROSPECTS

The Future Manufacturing Plant

By revolutionising R&D, the plant, the supply chain, product delivery, and customer service, the "Factory of the Future" is testing the limits of Industry 4.0. Figure 12 depicts the progression from the traditional factory to the smart factory of today and eventually to the Shop Floor 5.0. Below is a breakdown of the projected advantages of Shop Floor 5.

Prioritize the satisfaction of your customers.

We're talking about extreme personalization here.

• A flexible and decentralised supply chain.

• Product lines that are activated by the user's experience.

Re-employment of factory workers.

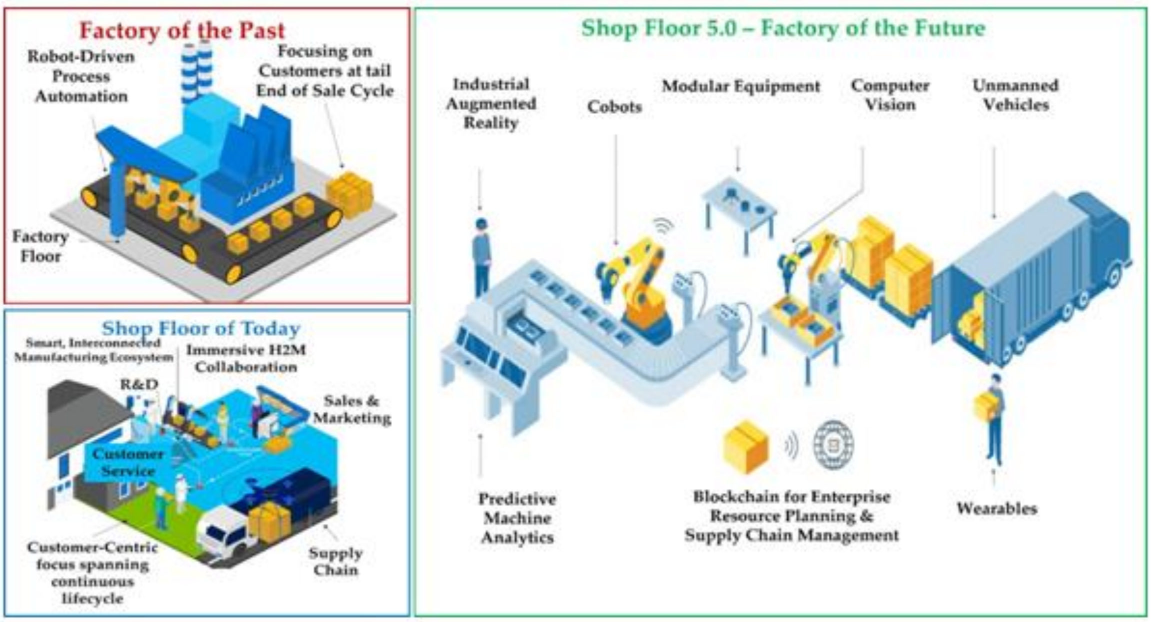

Figure 12. Towards Shop Floor 5.0 (derived from [68]).

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It is easy to see why Industry 5.0 is seen as a progression, merging essential components of Industry 4.0 into a bigger vision that benefits a wider group of stakeholders, given the commitment of the European Union and others toward a more sustainable future. The goal is to replace outdated forms of value production that are dependent on extracting wealth from the economy and natural resources with newer, more equitably distributed alternatives. The objective is broader than simply increasing profits for shareholders; it is instead motivated by concepts of regenerative purpose and the reconfiguration of industrial production. Table 6 below outlines the main differences.

New objectives for DX, new business models, value chains, and supply chains, new economic priorities for measuring industry performance, new approaches to policymaking that better align the interests of business and industry, new ways to drive innovation and research capabilities, and new ways to better align the interests of businesses with the public will all be necessary for Industry 5.0 to be a success. As a result, the pandemic has taught us that there is an immediate need to increase resilience throughout value chains while also protecting jobs and the economy.

Table 6. Comparison of Industry 4.0 versus Industry 5.0 [69].

Industry 4.0	Industry 5.0
• Centered around enhanced system and process efficiency through digital connectivity and AI • Technology-centered based on the implementation of CPS • Aligned with optimization of business models within existing capital market dynamics and economic models—i.e., directed towards the minimization of costs and maximization of profit for shareholders • No focus on design and performance dimensions essential for systemic transformation and decoupling of resource and material use from negative environmental, climate, and social impacts	• Ensures a framework for industry that combines competitiveness and sustainability, allowing industry to realize its potential as one of the pillars of transformation. • Emphasizes impact of alternative modes of (technology) governance for sustainability and resilience. • Empowers workers using digital devices, endorsing a human-centric approach to technology. • Builds transition pathways towards environmentally sustainable uses of technology. • Expands the remit of corporation's responsibility to their whole value chains. • Introduces indicators that show, for each industrial ecosystem, the progress achieved on the path to well-being, resilience, and overall sustainability.

Abilities for the Actualization of Society Version 5.0

The concept for Industry 5.0 goes beyond the technology and business principles of Industry 4.0 by focusing on three pillars like Human Centricity, Resilience, and Sustainability. Many companies are currently completely committed to developing technology-enhanced processes and systems, making this an ideal time to anticipate the next wave of innovation. There are ten (10) core competencies that manufacturers of the future will need, as recognised by the World Manufacturing Forum (WMF) [70]. Skills in digital and technological fields, as shown in Figure 13, are essential, but so are the more general cross-functional talents of creativity,

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adaptability, and openness of mind. Leaders, managers, and frontline workers alike will need to evolve and improve in response to the challenges of Industry 5.0.

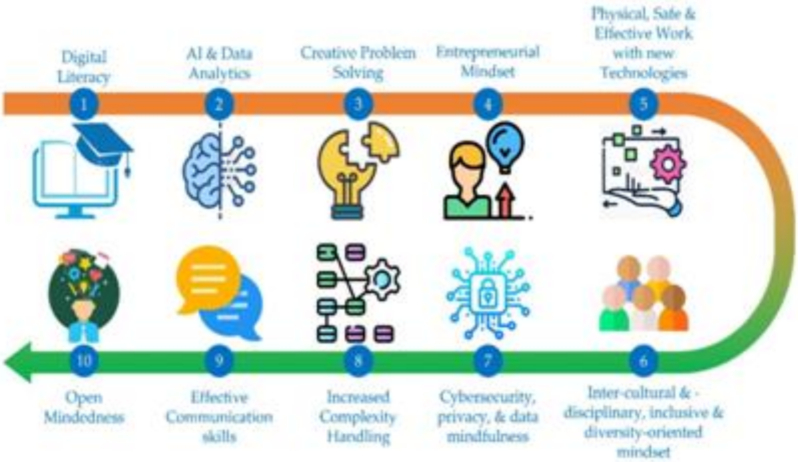

Figure 13. Ten Critical Skills facilitating the realization of Society 5.0, derived from [70]).

The concepts and theoretical underpinnings of digital transformation have been the subject of much study. These days, even top-level executives are tech savvy and familiar with the digital business world. After establishing a firm foundation, it's best to shift focus to including Human Centricity, Resilience, and Sustainability. Here are a few ideas that will be crucial in the years to come:

The emphasis must shift back to people.

Encouragement of resiliency.

Sustainability's importance has been emphasised.

Even while it's crucial for businesses to get ready for Industry 5.0, numerous external factors are pushing them to prioritise human-centeredness, resilience, and sustainability. Rather than rushing to fix a problem after it has already occurred, you should take this opportunity to strengthen your defences. So, beyond the standard "better, cheaper, and quicker," Industry 5.0 aims to steer the next generation toward a set of decisions that will make industries smarter, greener, and more resilient.

Repercussions for Study, Clinical Work, and Society

The lack of a universal rate of technological progress is one of the most important consequences that has been uncovered so far [60]. In the context of Industry 4.0, this is a particularly salient conclusion. To date, however, it has not received sufficient attention. Since the gap in technology is most pronounced between industrialised and developing nations, it is crucial that

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all three spheres of society work closely together to close it [71]. It also has major repercussions for the modernization of educational institutions. In particular, society expects universities to be sources of knowledge for emerging technology and novel approaches to societal problems. A universal technical bar can be reached in a number of ways. The United Nations' Sustainable Development Goals (SDGs) aim to mitigate, if not eradicate, the world's most pressing social problems. One alternative is for the international community to actively encourage and assist R&D initiatives in poor nations. Finally, rich nations might help less developed ones by providing technology and other solutions to speed up growth in the latter.

Probable Obstacles and Prospective Benefits

The digital and ecological shifts of Industry 5.0 and Society 5.0 are designed to foster a culture in which individuals may continue to live with purpose and originality. Thus, the roles of universities and corporations in reaching this objective will grow. As we strive for a more people-centered way of life, it is essential that we pair advances in IT with programmes that train the next generation of industry leaders with the skills they need to become effective information consumers. Universities, in addition to improving technology as they have in the past, are now responsible for encouraging literacy among information users by shifting their focus from broad, impersonal courses to more targeted, individual instruction [60].

For the sake of brevity, it is sufficient to emphasise that Industry 5.0 is an essential aspect of the larger Society 5.0. Inevitably, the forthcoming fifth industrial revolution will hasten the advancement of humanity. Furthermore, society's progress will help usher in the next industrial revolution. Table 7 sums up the shared challenges and opportunities between Industry 5.0 and Society 5.0.

Table 7. Summary of challenges and opportunities.

Similarities between Industry 5.0 and Society 5.0	
Challenges	**Opportunities**
1. Aging population	1. Human-Cyber Physical Systems (HCPS)
2. Resource shortage	2. Green Intelligent Manufacturing (GIM)
3. Environmental pollution	3. Human-Robot Collaboration (HRC)
4. Complex international situations	4. Future Jobs and Operators 5.0
	5. Human Digital Twin (HDT)

Industry 5.0 and Society 5.0: A Proposed Framework for Their Implementation

Compliance of technologies, activities, and adjustments with the SDGs as set by the UN is a crucial part of Industry 5.0 and, by extension, Society 5.0. In order to completely grasp the notion of Society 5.0, it is vital that academics, industry, and the other concerned groups come

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together and enhance their relationship. Therefore, future research will concentrate on bridging the divide between society, industry, and academia through the design, development, and deployment of frameworks that incorporate the technologies mentioned above (see Figure 14). In particular, the link between Industry 4.0 and Society 5.0 is illustrated in the conceptual framework shown in the aforementioned picture. As a corollary, it is emphasised that the technical progress made thus far is not squandered, but is instead redirected toward the development of the "super intelligent society" referred to in the preceding paragraphs. Two important reference architectures are also presented at the bottom of the framework: I the RAMI 4.0 and (ii) the Society 5.0 Reference Architecture (S5RA), which was first announced by the Cabinet Office in 2018 in the "Policy for the Development of a Data Exchange Platform" and has been the subject of ongoing study and development since then. RAMI4.0 is centred on the technical and organisational structure of businesses, whereas S5RA is concerned with a broader range of issues, including those pertaining to society at large. For this reason, the two reference designs do not compete with one another but rather reinforce one another. The link between business, culture, and learning is therefore emphasised. After multiple proof-of-concept tests conducted by the Cross-ministerial Strategic Innovation Promotion Program, the S5RA has been refined over the past few years (SIP). Despite being an entirely new reference design, the S5RA draws inspiration from RAMI4.0, and a layered structure has been adopted, as shown in the lower right section of Figure 14, consisting of a cube form similar to the EA3 cube framework. Here are the three dimensions: Time and place are represented by the x-axis, subjects by the y-axis, and meaning by the z-axis. The need of making good use of data and information is emphasised. When it comes to data and data federation, in particular, two of the architecture's layers are devoted to those activities alone. Concurrently, security and authentication mechanisms shield each tier of the architecture.

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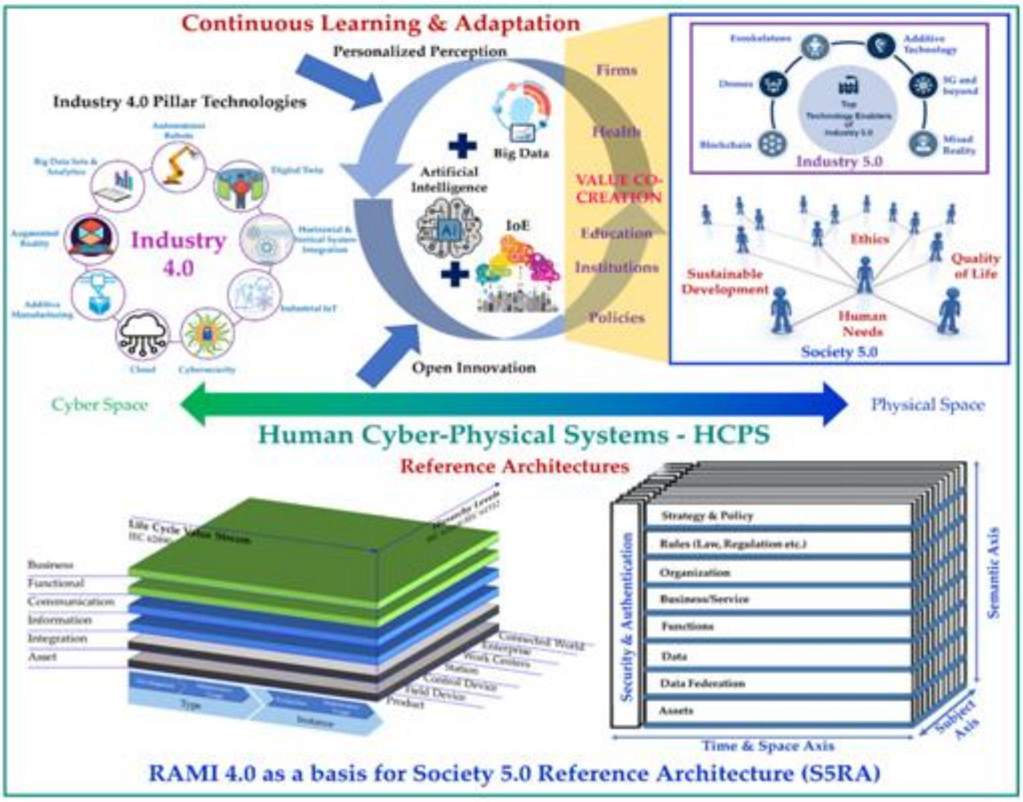

Figure 14. Industry 5.0 and Society 5.0 conceptual framework based on the integration of Industry 4.0 reference architecture model and technologies.

In addition to the detailed explanations of the reference architectures' inner workings, two paradigms—specifically, I Personalized Perception [60] and (ii) Open Innovation [71]—are made available. When it comes to customised perception, the framework of the paradigm may be broadened towards societal personalised perception, even if the authors in [60] focus on Education for analysing the unique requirements and strengths of pupils through the use of key technologies of I4.0. In a similar vein, the authors in [71] explore the benefits of Open Innovation in facilitating the shift to Society 5.0 via bolstering value co-creation through the joint pursuit of shared objectives by a variety of parties.

Future Prospects and Conclusions

In this study, we conducted a thorough literature evaluation on the impending Industry 5.0 and Society 5.0. By advancing a conceptual model in a field that has not yet been thoroughly studied in the literature, this study aimed to compile a review of relevant literature and provide a snapshot of the most important elements and technologies involved in the transition from Industry 4.0 to Industry 5.0 and Society 5.0.

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The investigation of scientific published works and the documentation from governments and organisations working on such initiatives has led to the safe conclusion that Industry 5.0 is much more than a trend, and thus Society 5.0 will open up previously unimaginable opportunities towards the development of a highly intelligent global society. The literature review included a discussion of the relevant technical context in order to provide light on the existing state of technological preparedness and forthcoming developments. All of the aims of the article were accomplished, and all of the questions that were posed were answered. To begin accomplishing our primary objective, we looked into the connection between Industry 4.0 and Society 5.0 and what we found was fascinating. The findings showed how the technologies that aid in building a physical-to-digital-to-physical loop, which is essential for the sustainable development of a human-centered society, are the key connecting factor. Our investigation into the gap between Society 5.0 and Industry 4.0 identified three major challenges that must be overcome. These are (1) human-oriented activity, (2) sustainable development, and (3) the physical to digital to physical loop. At the literature and bibliometric analysis step, we additionally clustered word sets for the primary keywords "Industry 5.0" and "Society 5.0." This showed that throughout the time period analysed, the environment, the Internet of Things (IoT), artificial intelligence (AI), and digitization were among the most prominent fields alongside society and the economy.

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