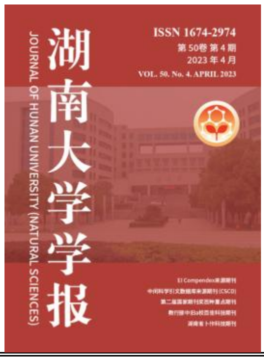

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From Industry 4.0 to Industry 5.0: The Transition to Human Centricity and Collaborative Hybrid Intelligence

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Abstract: Bringing back the human to the center of the industrial process, "with the robot" is no longer just a simple trend in today's society, especially considering the recent health crisis (Covid-19). In this context, Industry 5.0, considered the next industrial revolution, aims to combine the creativity of human experts with effective, intelligent, and precise machinery to provide manufacturing solutions that are more user-friendly and resource-efficient than those of Industry 4.0. Industry 5.0 is anticipated to benefit from various promising technologies and applications that will enable increased production and rapid supply of customized products. Industry 4.0 is regarded as technology-driven, while Industry 5.0 is a value-driven evolution of the previous one. The coexistence of two industrial revolutions raises issues that call for debates and explanations. This paper aims to study the main differences between revolutions 4.0 and 5.0, address the transition from Industry 4.0 to Industry 5.0, and discuss how human centricity and collaborative hybrid intelligence will support business processes in the industry 5.0 era. Besides, the benefits and challenges of the fifth industrial revolution were also presented.

Keywords: Industry 5.0, Industry 4.0, human-centricity, collaborative intelligence, human-robot collaboration.

从工业4.0到工业5.0：向以人为本和协作混合智能的过渡

摘要：将人带回工业过程的中心，“与机器人一起”不再只是当今社会的简单趋势，尤其是考虑到最近的健康危机(新冠肺炎)。在此背景下，被认为是下一次工业革命的工业5.0旨在将人类专家的创造力与有效、智能和精确的机械相结合，提供比工业4.0更人性化和资源效率更高的制造解决方案。工业5.0预计将受益于各种有前途的技术和应用，这些技术和应用将使定制产品的产量增加和快速供应成为可能。工业4.0被视为技术驱动，而工业5.0是前一个价值驱动的演变。两次工业革命的共存提出了需要辩论和解释的问题。本文旨在研究革命4.0和5.0之间的主要区别，解决从工业4.0到工业5.0的过渡，并讨论以人为本和协作混合智能将如何支持工业5.0时代的业务流程。此外，还介绍了第五次工业革命的好处和挑战。

关键词：工业5.0、工业4.0、以人为本、协同智能、人机协作。

1. Introduction

To meet the challenges of a dynamic, highly competitive global market, manufacturers must constantly upgrade their manufacturing systems to a smarter level. The successful integration of advanced information technologies and techniques, the Internet of Things, Big Data, and Cyber-Physical Systems are just a few examples of manufacturing processes resulting in digital manufacturing systems that are part of Industry 4.0. The term "industry 4.0" was coined in 2011 at the Hanover Fair, and it arose from a project in the German government's high technology strategy. It is the fourth industrial revolution, following the first three [1], see Fig. 1. The Industrial Revolution began in 1765 and since then, there have been numerous developments in the manufacturing field [2]. The first industrial revolution (Industry 1.0) occurred in the 18th century when primary machines were developed to reduce human and animal-powered machinery, which was then replaced by steam and water-powered mechanization in manufacturing units [3].

The second industrial revolution industry 2.0 occurred in the nineteenth century because of the emergence of electricity and the assembly line concept in 1870, which resulted in the concept of mass production with faster manufacturing and lower costs by using special-purpose machines to produce similar parts with the same design, leading to increased productivity and economic prosperity [2].

The adoption of computer-integrated automated and flexible manufacturing systems ushered in the third industrial revolution in 1950. Tasks previously performed by humans were replaced in Industry 3.0 by programmable manipulators such as robots and programmable logic controllers (PLCs) [3].

The fourth industrial revolution based on automated and networked cyber-physical systems, began in 2010. Intelligent decisions can be made in real-time through the manufacturing system using industry 4.0 key technologies such as cloud computing, big data, augmented reality and the Internet of Things, which ensure real-time communication between manufacturing things. This allows flexibility, efficiency, and high-quality product personalization.

As businesses began to embrace Industry 4.0, the fifth industrial revolution dawned. Michael Rada presented the notion of Industry 5.0 in a published article on the social networking website LinkedIn on December 1, 2015 [4].

Industry 5.0 is already having an impact on production, and it will change businesses because of using intelligent devices, allowing customers to get personalized products and services that match their unique demands [2]. Industry 5.0 is a resilient provider of prosperity that values social ideals that extend beyond jobs and growth, thanks to a worker-centered production method and respect for our planet's boundaries [1].

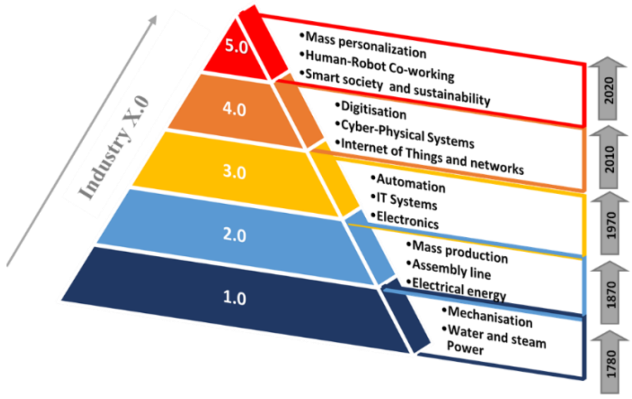

Fig. 1 Illustration of industrial revolutions from 1.0 to 5.0 [2, 5]

To improve production flexibility and efficiency, industry 4.0 focused on digitization, networked systems, big data, artificial intelligence-driven technologies, and robots. While industry 5.0 places a greater emphasis on the industry's ability to achieve social justice and sustainability principles, as well as the people who work in it with their human intelligence, which will collaborate with cognitive computing or robots to produce more value-added products and services [6].

This collaboration will bring about a change in an "age of augmentation," in which Industry 5.0 will usher in advanced human-machine interface technologies, sparking new debates about the resulting new working practices, such as the "smart working" practices described by Bednar and Welch [1, 7].

Some questions should be considered in this context, where Industry 4.0 and 5.0 coexist and machines and humans collaborate:

What are Industry 4.0 and Industry 5.0 and their technologies?

What are the primary distinctions between Industry 4.0 and Industry 5.0?

How can the transition from Industry 4.0 to Industry5.0 be made?

How can human centricity and collective hybrid intelligence improve business processes adopting Industry 5.0?

In order to address our research questions, we used databases such as Web of Science and Science Direct and searched for articles using specific keywords such as "Industry 4.0", "Industry 5.0", "human-centric", "Collaborative Intelligence", and "Collective Intelligence" (Fig. 2). In addition, the articles we selected were required to meet certain criteria to ensure relevance and timeliness. Specifically, we only included articles that were relevant to the research questions we were investigating and were recent enough to reflect current thinking and developments in the field. After applying these criteria and reviewing the titles and abstracts of the articles, we were able to select 40 articles that met our standards and served as the basis for our research project.

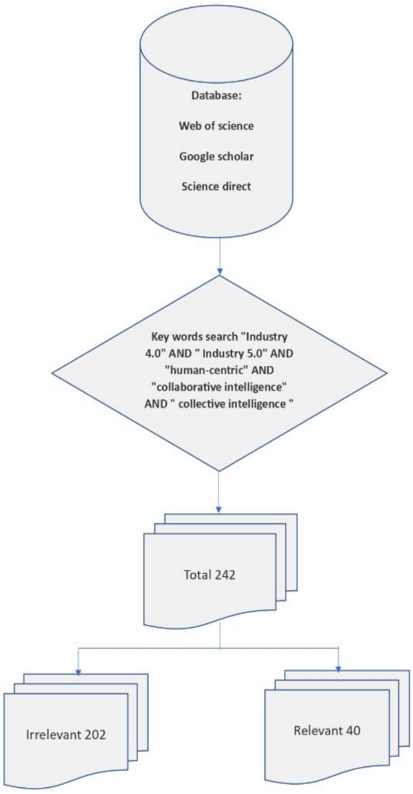

Fig. 2 Flowchart of the research methodology

This paper is organized as follows: the second section introduces industry 4.0 and industry 5.0 and their core technologies, respectively, and the third section relates the main differences between Industry 4.0 and Industry 5.0.In the fourth section, we presented how to transition from Industry 4.0 to Industry 5.0.

In the fifth section, we deal with the role of human centricity and collective intelligence in improving business processes. The sixth section discusses the major issues of industry 5.0 adoption, the advantages, and the challenges. We conclude this paper in the seventh section.

2. Industry 4.0 and 5.0 Technologies

2.1. Industry 4.0 Core Technologies

By integrating many technologies into the manufacturing system, Industry 4.0 changed the manufacturing sector [8]. Its main goal was to achieve smart manufacturing by connecting machines and equipment that controlled each other throughout the process lifetime, reacting to changes in real-time in the factory, supplier network, and customer requirements.

Industry 4.0 focuses on process automation, mass productivity, and performance improvement by using various technologies [2]. These technologies can be divided into two categories: physical and digital technologies [9].

Sensors, drones, and additive manufacturing are all examples of physical technology. Digital technology encompasses both current and classic information and communication technologies, such as big data analytics and cloud computing. The table 1 outlines the various digital and physical technologies used in Industry 4.0.

Table 1 Industry 4.0 technologies [9]

Physical/Digital	**Technologies**	**Definition**
Physical	Additive Manufacturing (3D printing)	It is a manufacturing technique that uses several additive or layered development frameworks to construct three-dimensional (3D) solid items
	Autonomous robots (Robotics)	In manufacturing, they are used to replicate human operations
	Cobots	They are robots designed to interact physically with humans in a co-working space
	Unmanned aerial vehicles (Drones)	A drone is an aircraft that does not have a human pilot on board
	Global Positioning System (GPS)	GPS is a technological marvel made possible by a cluster of satellites in Earth's orbit that emit precise signals that allow GPS receivers to calculate and show exact location, speed, and time data to users
	RFID	Refers to technologies that monitor and identify objects through wireless communication between an object (or tag) and an interrogating device (or reader)
	Sensors and actuators	Is a device that detects and transmits an impulse in response to a physical input (such as heat, light, sound, pressure, magnetism, or a specific motion) (as for measurement or operating a control)
	Nanotechnology	Known as molecular nanotechnology, it is a technique for controlling individual atoms and molecules to fabricate macroscale goods
Digital	Artificial intelligence	It is a branch of computer science that focuses on the development of intelligent machines that function and react in the same way that humans do
	Augmented reality	Is a form of interactive, reality-based display environment that uses computer-generated displays, sound, and other elements to augment the real-world experience.Instead of transporting the user to a virtual environment as VR does, it mixes the virtual elements with the real world [10]
	Big data and analytics	When typical data mining and handling approaches fail to extract insights and meaning

	from the underlying data, this strategy for evaluating vast amounts of data is applied. Big data is a driver key to intelligent manufacturing [11]
Blockchain	It is a distributed database that uses innovative encryption and authentication technology as well as a network-wide consensus process to maintain a truly dispersed and non-tampering continually increasing list of records
Cloud	Any IT services that are provisioned and accessible through a cloud computing provider are referred to as cloud computing services
Cybersecurity	Refers to the measures put in place to prevent data from being stolen, hacked, or damaged and is a critical concern in manufacturing [12]
The Industrial Internet of Things	Collection of hardware devices that work together to improve manufacturing and industrial processes via the Internet of Things connectivity
Mobile Technology	Wireless device-based integration of wireless communication technology
Simulation	Computer-based technologies that replicate a real-world process or system

Industry 4.0 technologies have different applications in several fields. Smart factories, for example, deploy technology such as cobots to complete routine and repetitive operations in day and night shifts without coffee or lunch breaks. Leaving jobs that are not codified or require an implicit understanding of human intelligence. The diagram below shows how Industry 4.0 is implemented in a smart factory using cobots [13].

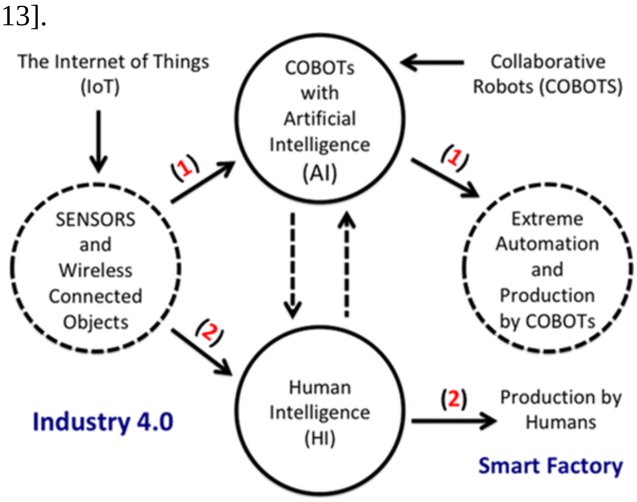

Fig. 3 Industry 4.0 in smart factories [13]

Sensors integrated with animate and inanimate objects collect and communicate Big Data to (1) cobots in smart factories that employ AI to accomplish massive automation and productivity in a variety of locations and time zones throughout the world.Sensors provide Big Data to (2) human intelligence (HI) and production when the complexity of sense-making exceeds a specific threshold or requires tacit contextual knowledge. Humans may refer to tasks back to cobots after providing contextual or tacit information (note the two-directional dashed lines between AI and HI in the figure). “Cobots” stands for collaborative robotics, while AI stands for artificial intelligence [13].

All these digital and physical technologies, as well as automation in interconnected industrial systems, will profoundly affect and effect the industry's economic position as well as society as a whole since workers' roles will be altered or indeed threatened. As a result of these changes, the industry will have to reconsider its place and role in society [6].

2.2. Industry 5.0 Core Technologies

Many technical experts believe that Industry 5.0 will reinstate the human touch by implementing industry 4.0 principles of advanced digitalization, big data, the internet of things, artificial intelligence and automation to boost productivity [14] while focusing on new emergent requirements in the industrial, societal and environmental landscape [6]. This involves raising productivity and increasing the flexibility and robustness of value chains in a context that is suited to the human worker while also taking full advantage of technology for circularity and sustainability.

In the globalized world where we live now, the industry should adopt responsible innovation and reconsider its environmental and societal goals. By changing its profit-driven approach to become a true provider of prosperity, by going far beyond the increase of cost-efficiency to the increase of prosperity for all these parts: society, environment, workers, consumers, and investors [6].

Technology advancements impact how value is created and exchanged. And distributed in industry 5.0 this technology is designed around three interconnected values.

2.2.1. Human-Centricity

In this approach, the production process of the industry places the fundamental demands and interests of people at its center to change the industry from a technology-driven to a human and society-centric driven approach. This means not considering the worker as a cost any more but as an investment, and rather than asking him to adapt his skills to the increasingly-changing technologies, these technologies should be used to adapt the production process to guide and train him while preserving his fundamental rights such as autonomy, right to privacy, and human dignity [15]. The working environment should be safe and inclusive to prioritize physical and mental health and support workers to up-skill and re-skill themselves for better career opportunities and work-life balance [1].

2.2.2. Sustainability

Industry has to respect the boundaries of the planet and ensure that without compromising the demands of future generations, it must be sustainable; this means that circular processes should be designed in a way where natural resources are reused, re-purposed, and recycled to minimize environmental impact and reduce waste. This can be achieved using technologies such as artificial intelligence and additive manufacturing that would help optimize resource efficiency and reduce energy consumption and greenhouse emissions [1].

2.2.3. Resilience

Defined by the European Commission in its Research & Innovation paper about industry 5.0 as «the need to develop a higher degree of robustness in industrial production, arming it better against disruptions and making sure it can provide and support critical infrastructure in times of crisis» [1].

There are different types of crises, such as natural crises or geopolitical shifts. A recent concrete example is the COVID-19 pandemic, which highlighted the fragility of current globalized production.For balanced production, resilient strategies should be implemented in value chains for more adaptable production capacity and flexible business to serve basic human needs such as food, healthcare, and security (Fig. 4).

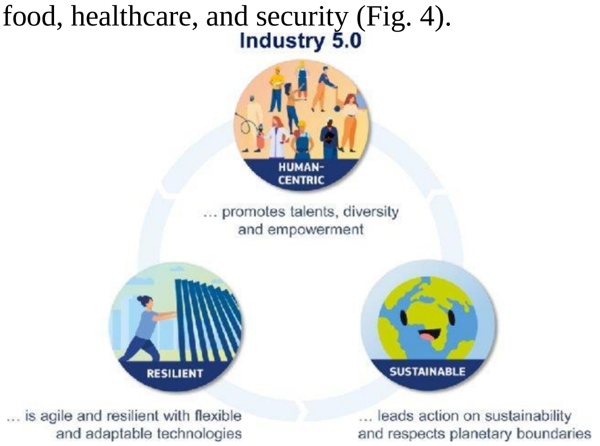

Fig. 4 Industry 5.0 core values [6]

Industry 5.0 to be human-centric, sustainable and resilient needs several technologies to achieve each value. These are the enabling technologies of Industry 5.0 (Fig. 5):

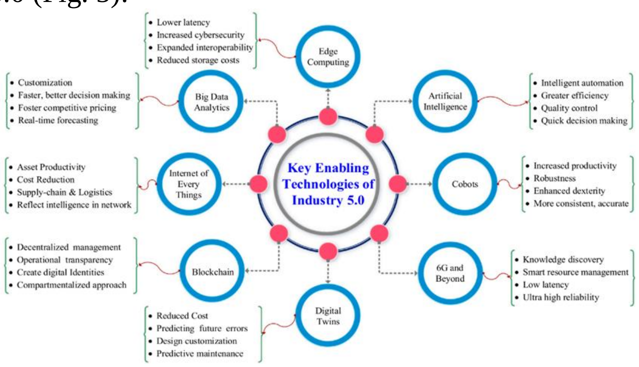

Fig. 5 Industry 5.0 key enabling technologies [14]

3. Industry 4.0 vs. Industry 5.0

When manufacturing is done according to Industry 4.0, it generally uses the Internet of Things (IoT), Cloud computing, cyber-physical systems, artificial intelligence, as well as intelligent devices and machines, to develop a controlled smart network [16]. This will overcome difficulties including improper tool selection, overproduction, and a lack of transparency.

On the other hand, Industry 5.0 builds a smart production system with a proper digital connection. To improve the capacity for research and development, it will use the data intelligently and implement automatic processes [17-19]. To enable flexible industrial processes to communicate with one another, several factories will be connected. The table below explains the main differences between Industry 4.0 and Industry 5.0. We reconsidered the differences cited by Mohd and Javaid and added others (Table 2)

Table 2 Differences between Industry 4.0 and 5.0 [2]

Industry 4.0	**Industry 5.0**
Industry 4.0 prioritizes mass product customization	Industry 5.0 prioritizes mass personalization of the product
Uses data digitally	Uses data intelligently
Offers a unique experience	Offers an innovative experience
Assures better coordination between machines and information technology	Seeks close collaboration of humans with machines
Seeks digital factories creation	Creates smart factories
Performws all customized tasks in less time and cost	Performs precise and creative tasks in less time and cost
Creates digitization and automation by applying information technologies	Globalizes the manufacturing system using advanced technologies
Quality control is data-driven, it predicts the material behavior	Quality control is creativity-driven and predicts material and product behavior
Uses efficiently machines and information technology	Uses efficiently the workforce of machines and people in synergy with the environment
The core of Industry 4.0 is connectivity through cyber-physical systems	Industry 5.0 revolves around "man and machine," often known as robots or cobots, and their relationship
When implementing Industry 4.0's pillars, the workforce is envisioned as being far from manufacturing	In Industry 5.0, workers are required inside factories to include the human factor in processes
Industry 4.0 focuses on technology and automation	Industry 5.0 consists of reviewing technological foundations and promoting actions for social transformation and human resources

4. The Transition from Industry 4.0 to Industry 5.0

The humanization of the Industry 4.0 evolution and its transition to Industry 5.0 is linked to the Operator 4.0 concept, which has been presented as a people-focused view of the fourth industrial revolution and a form of human-machine collaboration. This concept was later expanded to include a resilience dimension, resulting in the concept of Operator 5.0 [20].

According to [21], this resilient Operator 5.0 vision focuses on creating "self-resilience" for employees who possess natural weaknesses and fragility, as well as "system-resilience" for optimal system performance through smarter operator-machine collaboration. Therefore, mixed reality frameworks and platforms should be used to train such professionals.

Industry 5.0 is seen as a value-driven field, while Industry 4.0 is more technology-driven, making them capable of coexisting. This has resulted in the emergence of a Techno-Social-Revolution, in technology as the tool and societal needs as the goal. We can see this transition from Cyber-Physical Systems in Industry 4.0 to Cyber-Physical-Social Systems in Industry 5.0, making it possible to increase productivity without removing human workers from processes [1]. Nahavandi sees this coexistence as robots working in collaboration with the human mind creating more jobs than it takes away [22]. A recent review argues that both frameworks can coexist peacefully, with Industry 5.0 supplementing the existing framework of Industry 4.0 and its focus on workers during this COVID-19 pandemic [23].

The transition from Industry 4.0 to Industry 5.0 has been proposed by Saniuk et al. [24], focusing on human-centric, sustainable, and resilient principles to ensure sustainable development and quality of life. Investment strategies and government policies must be changed to support this move, which people must understand as the path to progress and betterment of all. Ungureanu [25] stresses the implementation of the 4Cs (critical thinking, communication, collaboration, and creativity) as a way to acknowledge the worth of human capital during transformation. Information and communication technologies are mentioned as key in an article from Jafari et al. [26], whose aim is to embed human-centricity, resilience, and sustainability into Industry 4.0 for Industry 5.0's requirements - requiring new consideration for technology matches. The new role of humans in this technological transition must prioritize economic, environmental, and societal sustainability. Some resistance from employees toward this change has been reported [27] due to the fast pace of technological advancement compared to reaction speed.

When discussing "smart factories", one must consider the: are they smart primarily due to human influence or robotics and AI technology? Currently, Industry 4.0 is more geared toward automation, while Industry 5.0 tends to emphasize the importance of humans. A hybrid of the two may be the best approach as it can utilize both in a collaborative intelligence setting [28].

5. Human Centricity and Collaborative Hybrid Intelligence

In the human-centric approach of Industry 5.0, the workers role will change considerably. The worker is not a cost anymore but an investment to develop for the company. Tough companies will invest in the skills, capabilities and well-being of the worker to achieve together their objectives.

From the Industry 5.0 perspective, the technology serves the human; this means that instead of having the worker adapt to ever-evolving technology, the manufacturing technology will be adapted to the worker’s needs and diversity. To achieve this, workers should be included in the design and application of industrial new technologies such as artificial intelligence.

This involvement of workers in shaping production processes can be achieved virtually. A virtual factory could be very helpful in testing and developing ideas in the co-design phase in collaboration with workers and other community members. The Factory2Fit project is a good example of the implication of workers in the design of the process; the project aims at engaging workers in the connected industrial environment by developing a worker Feedback Dashboard that gives feedback on one's accomplishments and well-being. The first results of this experience were satisfying, and a positive impact on productivity and worker well-being was obtained. These results are proof of the possibility of linking human expertise with ever-increasing automation [6]. Such initiatives empower the human-centric approach and identify a new role for workers in the industry 5.0 age.

Industrial processes typically have several decision-making points, and for them succeed, the decisions must be both effective and efficient. As Industry 4.0 processes move toward automation and autonomy in decision-making, Industry 5.0 is expected to involve people being central to the decisions. Usually, it takes a group of decision-makers to come together and make decisions as a collective intelligence. We predict that a mix of people and autonomous agents will be part of the hybrid collective intelligence driving decision-making in the Industry 4.0 - Industry 5.0 hybrid [28].

Collective intelligence is enabling a “social” level to be added to cyber-physical systems, thus creating cyber-physical-social systems that are self-organizing and crowd-driven [29]. This layer has also been applied to product manufacturing, resulting in “social manufacturing” [30], which involves the need for service principles, gathering people together, and facilitating complex collective intelligence networks. Nguyen et al. [31] assert collective intelligence as an intelligent activity of a group of autonomous units (people or systems) having both cooperation and competition properties. Williams [32] states that general collective intelligence is necessary for the pervasive use of pervasive manufacturing as it enables groups to work collaboratively as one collective intelligence, resulting in increased problem-solving ability. Smart manufacturing necessitates the use of efficient collective intelligence, especially computational collective intelligence.

6. Discussion

Many social issues are of concern today. Actually, the sectors moving toward digital transformation under the scope of Industry 4.0 and 5.0 may see job losses within their current workforces. The change will probably open up more opportunities in new fields such as data warehousing and robotic process automation (RPA). For improved prospects, the workforce should upgrade to newer and more pertinent skill sets. To close the skill gap and meet the most urgent needs, ongoing training and workforce development are required.

The skills necessary to execute the work are anticipated to alter because of the shift in business practices brought about by Industry 5.0, which will lead to the formation of skills gaps. Businesses that take proactive steps to fill these skills gaps in the industry 5.0 era will have a strategic edge. However, understanding the in-demand skills is the main foundation for forecasting skill gaps.

The most in-demand skill that will be needed by the year 2025, is problem-solving, which involves analytical thinking, critical thinking, creativity originality, innovation, and reasoning. As automation spreads throughout Industry 5.0, there is a chance that employees will be able to provide more value by tackling more challenging issues. Employees will have the chance to exercise a more critical thought in this situation. Employees are therefore expected to apply their problem-solving abilities both in the process of meeting the customized product/service demands of clients and in the process of human-robot-algorithm interaction.

In addition, the social effect of both leaders and employees will increase in the organization when they exhibit leadership behavior in line with Industry 5.0 [33]. According to “Social Impact Theory” [34], social impact is a social effect in which one can alter the values, emotions, thoughts, attitudes, and behaviors of others. Influencing individuals both inside and outside the corporation is anticipated to be one of the in-demand abilities in the industry 5.0 age.

It is projected that the green and digital changes brought about by Industry 5.0 will affect how employees communicate. Employees must be able to collaborate with machines and algorithms and people both inside and outside the company. To ensure that employees adapt and become more motivated, leaders must also exhibit a leadership style that is suitable for both the organization’s dynamic structure and the competitive environment.

Otherwise, digitalization, in particular, is a source of the technology-based competitive advantage that reinforces itself [35]. Hence, employees with the skills associated with technology usage and technology development can make distinct contributions to businesses. These workers are not only found in IT departments but also in marketing, production and sales or other departments.

In addition, Industry 5.0 combines human ingenuity with robotic accuracy to produce a special solution that will be in demand in ten years. Ansari et al. [36] explored the potential to have humans and machines not just operate but learn together, something that could turn today’s smart factories into self-learning settings. Such factories would be powered using processes that can switch between people and cobots in line with the intelligent distribution of tasks and from which both sides can learn from. To cope with the more complex and intelligent production settings, human-led collective thought needs to be developed into human-automation cooperation (collaborative cognition). Jiao et al. [37] note that this hybrid cognition offers various advantages, such as enhancing affective cognition, expanding perception, improving learning, establishing trust dynamics, predicting performance, and optimizing human-automation interaction.

Seen from an environmental perspective, the 2030 Sustainable Development Goals established by the UN are also strongly related to Industry 5.0. (SDGs).This is how actions are taken in the sector with a focus on sustainability and more efficient use of the planets natural resources.

Companies seem to be gradually realizing the effects of focusing only on production and profit. As Industry 5.0 expands ever faster, attention turns to how much business development is costing. Businesses are becoming aware of how their actions impact the environment. Therefore, with Industry 5.0, solutions to these issues become a reality and can enhance the state of the Earth as it is right now.

Of course, increasingly conscious consumers are also contributing to this transformation. When people or consumers start to evaluate company ethics and production processes concerned with the environment, companies need to adapt to this new demand and transform their products and processes to be aligned with environmental needs. This necessitates a change in perspective that emphasizes the value of and need to protect both people and the environment.

Nevertheless, the adoption of Industry 5.0 faces some challenges. First, investing in technology prevents industries from embracing version 4.0.Even if Industry 5.0 has more focus on the human element, technology investment is still critical and essential.

Second, the training of employees as professionals find it increasingly difficult to understand and deal with the new ever-changing world in which we live. Companies must conduct training and provide ample practice for employees to be able to adapt to this new context.

Moreover, to have resilient systems in the future, we need to design and build smooth human-machine teams. The concept of resilient Operator 5.0 is particularly important here. According to [38], active agent-driven interfaces (for IoT, services, and humans) can gather information on the agent status of new generation operators (Operator 5.0), social machines and social software systems and request cooperation to enable collaborative multi-agent environments such as [39] or [40]. This enables “twin agents” that connect actual humans and machines with the cyber and physical worlds.

7. Conclusion

Industry 5.0 emphasizes sustainability and cooperation between humans, robots, and algorithms. By putting humans at the core of the integrated system created by Industry 4.0, this cooperation can be achieved. As a result, Industry 5.0 has also been envisioned as an improved version of Industry 4.0 that is greener and more human centered.

After the COVID-19 health crisis, humans should be back at the center of the production process in collaboration with the robot. Of course, managers must find solutions to digitize processes and improve productivity in their factories. But it is also and above all a question of reducing the arduousness and repetitiveness of tasks and allowing operators to increase their skills.

In this paper, we relate the main differences between both revolutions 4.0 and 5.0 and illustrate how the workers role will change considerably in Industry 5.0.We concluded that employers should offer education and training programs to support workers' needs for the acquisition of new skills. They must be taught and “learn how to learn skills”. They will therefore be able to upskill and reskill; this ability will be crucial in the industry 5.0 transition phase.

Another aspect should also be considered to make pervasive manufacturing widely used, which is the adoption of collective intelligence (humans and machines) in business processes, as it allows different groups to work together and solve issues more effectively. Computational collective intelligence plays a particularly important role in smart manufacturing.

In summary, we can conclude that Industry 4.0 involves a major level of automation in the decision-making processes, whereas Industry 5.0 puts humans at the forefront of decision making. However, for the Industry 4.0 and Industry 5.0 mix, a combination of collective intelligence is necessary to drive efficient, ubiquitous, human-centric, responsible, and resilient decision making.

Future research efforts should concentrate on creating technologies that are transparent, reliable and quantifiable and that offer an enjoyable working environment that is motivated by practical requirements.

Notwithstanding, the following are some limitations presented in this article.

7.1. Limited Scope

The article only focuses on the role of workers in Industry 5.0 and does not address other aspects such as the impact on the environment, cybersecurity, or privacy.

7.2. Lack of Practical Guidance

While the article suggests that employers should offer education and training programs to support workers' needs for new skills, it does not provide specific recommendations on how to design and implement such programs.

7.3. The Biased Perspective

The article presents a positive view of Industry 5.0 and assumes that automation and human collaboration can coexist without conflicts. However, this perspective may not reflect the reality of some industries or workers who may perceive automation as a threat to their jobs or skills.

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