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Review

Is Industry 5.0 a Human-Centred Approach? A Systematic Review

Joel Alves [1,2], Tânia M. Lima [1,2] and Pedro D. Gaspar [1,2,*]

[1] Electromechanical Engineering Department, University of Beira Interior, Calçada Fonte do Lameiro, 6201-001 Covilha, Portugal
[2] C-MAST—Center for Mechanical and Aerospace Science and Technologies, Calçada Fonte do Lameiro, 6201-001 Covilha, Portugal
* Correspondence: dinis@ubi.pt

Abstract: Industry 5.0 presents itself as a strategy that puts the human factor at the centre of production, where the well-being of the worker is prioritized, as well as more sustainable and resilient production systems. For human centricity, it is necessary to empower human beings and, respectively, industrial operators, to improve their individual skills and competences in collaboration or cooperation with digital technologies. This research's main purpose and distinguishing point are to determine whether Industry 5.0 is truly human-oriented and how human centricity can be created with Industry 5.0 technologies. For that, this systematic literature review article analyses and clarifies the concepts and ideologies of Industry 5.0 and its respective technologies (Artificial Intelligence, Robotics, Human-robot collaboration, Digitalization), as well as the strategies of human centricity, with the aim of achieving sustainable and resilient systems, especially for the worker.

Keywords: Industry 5.0; human-centricity; human-centred; I5.0 technologies; artificial intelligence; robotics; cyber-physical systems; digitalization

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1. Introduction

The 4th industrial revolution and the concept of Industry 4.0 presented itself as a fourth technological wave, with an overwhelming impact on digital systems [1]. Industry 4.0 promotes high production efficiency and quality levels, and it is oriented toward innovation and industrial technology development [1,2]. Furthermore, Industry 4.0 has a techno-economic vision, i.e., for economic development through technological advances, and, therefore, at the industrial level, innovative technologies are used to improve value chains and cope with changing economic transformations [1]. However, although Industry 4.0 has not been fully implemented and integrated globally, companies and industries are faced with the arrival of the 5th Industrial Revolution, which will involve autonomous manufacturing, but with human intelligence [3,4]. When industries started their involvement and adaptation to Industry 4.0, the 5th Industrial Revolution and the concept and ideology of Industry 5.0 emerged [3]. It can thus be said that Industry 5.0 is a prolongation and chronological extension of Industry 4.0 [1]. Industry 4.0 has limitations with regard to industrial sustainability and workers' well-being, as it focuses on the efficiency and flexibility of production through digitalization and technologies [2,3].

Industry 5.0 aims to address the human challenges of Industry 4.0 as a human-centric solution [2], placing the worker's well-being at the centre of the production process [3]. The ideology of Industry 5.0 emerged in 2020, after discussions and sharing of ideas in two virtual workshops, and officially in January 2021, with its formal publication in the European Commission (EC) document [3,5]. The focus of the EC document is to foster transformation and drive change in companies and industries to make them more sustainable and human-centric [5,6]. Industry 5.0 is in parallel with European societal goals, i.e., in addition to job creation and resilient development, industrial sustainability

needs to be ensured by respecting the limits of our planet and the well-being of industrial workers [7].

Thus, while Industry 4.0 is an approach centred on technological digitalization, Industry 5.0 is an approach centred on humans through three core pillars: resilience, sustainability, and human centricity [8]. Industry 5.0 intends to capture the value of innovative digital technologies [8] and their human-machine interaction. Currently, the operator works alongside and with the assistance of machines in smart industrial environments [6]. The EC, with the introduction of Industry 5.0 within industry, aims to make workplaces more inclusive, as well as more resilient and sustainable ways of working [8].

In this article, a systematic review was conducted to clarify and assess the concept, ideology, and proposals of Industry 5.0. It is also intended to analyse the main concerns and challenges of human-centricity in future industrial environments and how Industry 5.0 technologies can help and boost the operator of the future. Hence, the study started with data analysis and relevant information on the theme. This information is divided into three lines of investigation: the first line of research is Industry 5.0 definition, ideas, and concepts; the second line of research is the analysis of the Technologies of Industry 5.0; and, finally, the third line of research focuses on Human Centricity. The discussion is also performed in stages: Industry 5.0 from an industrial perspective and in society; the centralization of the human being with Industry 5.0 technologies; the Industry 5.0 operator; and, finally, some challenges, limitations, and the future research agenda are raised. Thus, it is possible to determine whether Industry 5.0 is truly human-oriented and how human centricity can be created with Industry 5.0 technologies.

2. Materials and Methods

As Industry 5.0 and Human-centricity are hot and rising topics of the present times, in this work, a Systematic Literature Review (SLR) was conducted to collect, verify, analyse, and detail the available scientific data on the ideals, constructs, challenges, and limitations of Industry 5.0 as a strategy that places the human being at the centre of productive processes and systems. Thus, this SLR aims to establish a literature review process that allows the identification and interpretation of recent literature on the ideologies and strategies of Industry 5.0, with a focus directed to the centralization of the human being and especially to the operator in the industries. To perform this systematic review article, a four-phase flow diagram and the guidelines for Systematic Review and Meta-Analysis Statement, commonly known as PRISMA, were applied [9,10].

2.1. Focus Questions

Industry 4.0 turned out to be more technology oriented than human being oriented, neglecting the human factor in productive systems. Therefore, Industry 5.0 emerges as a complement and transitional ideology from a technological Industry 4.0 to an industry centred on the human being, where the worker's well-being is prioritized, but maintaining productive performance. The future perspectives for human-centricity are to empower humans and human operators by enhancing their individual capabilities and skills, i.e., human factors, and to achieve the balance and fullness of human-machine collaboration, i.e., to improve human-robot interaction in dynamic and complex industrial systems. Therefore, it is important to study and analyse the human-centricity strategies, introducing and evaluating the concepts and ideologies of Industry 5.0, Human Factors, and Industry 5.0 Technologies to achieve a sustainable and resilient system, especially for the worker, which leads to the research questions:

(1) Is Industry 5.0 truly human-centric oriented?
(2) How can we create human-centricity with Industry 5.0 technologies?

2.2. Information Sources and Data Collection Process

For this SLR article, the initial data collection and screening were processed in November 2022, and three electronic databases were used for the bibliographic research, namely,

Science Direct, Scopus, and Web of Science. For the database search, pre-determined keywords were used that are related to the principal focus of the study: Industry 5.0 and Human-centricity. Furthermore, Boolean operators were used to carry out this SLR. As previously stated, being a "fresh research" theme, the keywords were chosen to be comprehensive research and not to condition or restrict the study. Hence, potentially relevant data and information for the investigation would not be left out. Thus, the established search equation was (("Industry 5.0") AND (("Human-centric") OR ("Human-centered") OR ("Human-centred"))), and it was used in the advanced search of Science Direct and Web of Science. After that, the syntax was adapted for the Scopus database: TITLE-ABS-KEY (("Industry 5.0") AND (("Human-centric") OR ("Human-centered") OR ("Human-centred") OR ("Human centered"))). The language search was conducted in English and without any time restriction.

2.3. Eligibility Criteria

In this review, we analysed studies that present data about the ideologies of Industry 5.0 and strategies for human-centricity, especially for the factories of the future. The authors first conducted the preliminary selection and exclusion based on paper titles and abstracts. The screening process was performed by three authors. The following inclusion/exclusion criteria were employed for eligibility: only studies with full text available, published in English, including research articles, review articles, and conference papers that present and explore at least one of the two focus subjects of the study: Industry 5.0 and Human-centricity. In addition to these inclusion factors, others were added, such as sustainability, resilience, and technologies, when associated with Industry 5.0 and Human-centricity. Articles with an exclusive focus on technological advancement without human-centricity or articles that only suggested Industry 5.0 as a future perspective were excluded.

2.4. Principle Findings

This systematic literature search identified a total of 227 articles: 126 from Science Direct, 60 from Scopus, and 40 from Web of Science. Of these articles, 18 were not available for full-text reading and 52 were duplicates or triplicates, and because of that, they were excluded. Thus, a total of 157 articles remained after the exclusion of repeated articles. In the next phase, exclusion was performed by reading the titles and abstracts of the articles, excluding 85 and leaving only 72 articles. The next was to analyse the eligibility of these 72 articles by full-text reading, where 15 were excluded for not meeting the purpose of the current study. The remaining 57 articles were analysed and included in this systematic literature review (see Figure 1).

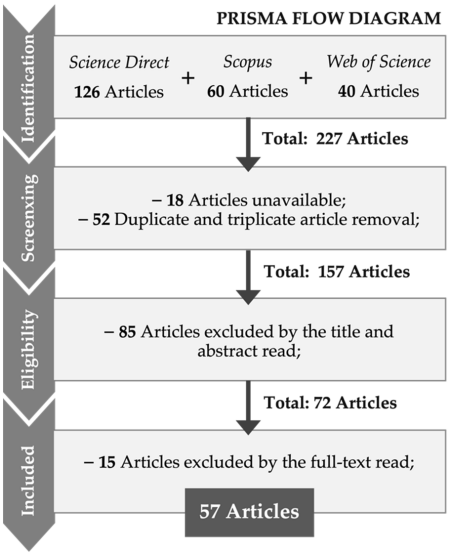

Figure 1. PRISMA flow diagram displaying the results of the systematic research.

The first analysis performed in this review article focused on the publication dates, location, and article type of the articles eligible and included in the study. Although no time restriction was applied in the search, the publication dates of the articles are very recent (from 2019 to 2023), which demonstrates the growing research on the concepts of Industry 5.0 and Human-centricity; specifically, there were a high number of publications in the year 2022 (Figure 2). The second analysis was to check the type of articles that were being produced and published on this recent theme. Of the 57 articles selected to be included in this review study, the majority are research articles, i.e., 36 articles, followed by 14 conference papers. In this short period of time, six reviews on different topics and aspects of Industry 5.0 have already been conducted (Figure 3).

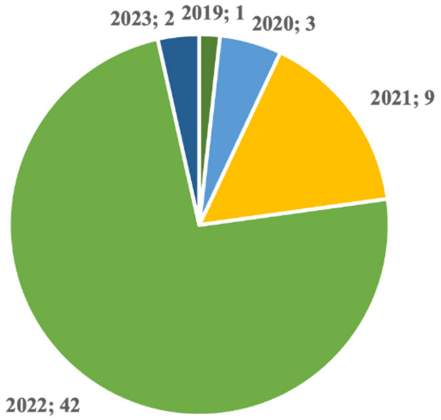

Figure 2. Number of articles published by year (Year; Number of publications).

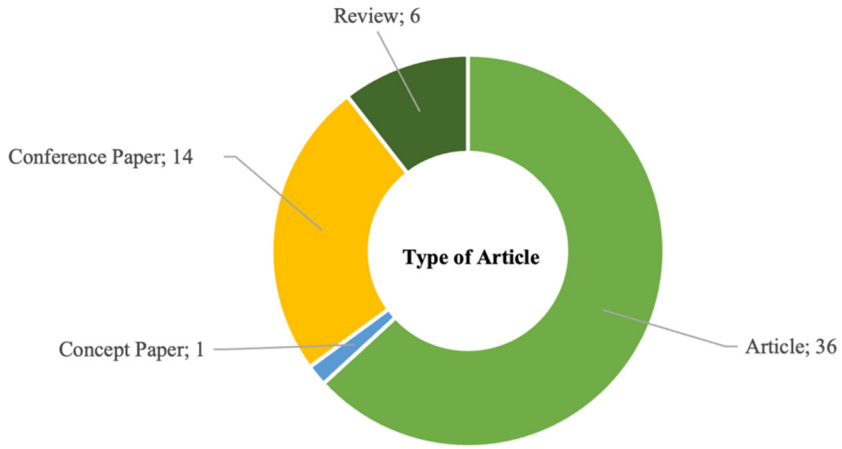

Figure 3. Type of articles.

Another feature evaluated was the occurrence of publications by location, as represented in Figure 4. To this end, the location of the first author or the respective affiliation was chosen for all articles included in the review to follow a homogeneous process. The countries with the highest number of published articles were Italy and Germany, followed by China, Sweden, and New Zealand. These are countries with a high degree of industrial development and, therefore, with a high potential for research and innovation.

In addition to these initial analyses and evaluations, the main keywords were verified, as well as their main relationships and interconnections. To this end, software named VOSviewer 1.6.17 was used to generate maps from the database information. VOSviewer is a free and easy-to-use program that is designed to construct and visualize bibliometric maps. This software can be applied in two ways: (1) to construct author or journal maps based on co-citation data or (2) to construct keyword maps based on co-occurrence data. VOSviewer allows bibliometric maps to be examined in detail through various functionalities, such as

zooming, scrolling, and searching [11]. In the case of this review article, a VOSviewer Map was created through the occurrence of the keywords. The software analysed the articles included and eligible for the study and created a map with the keywords that have a higher occurrence (Figure 5).

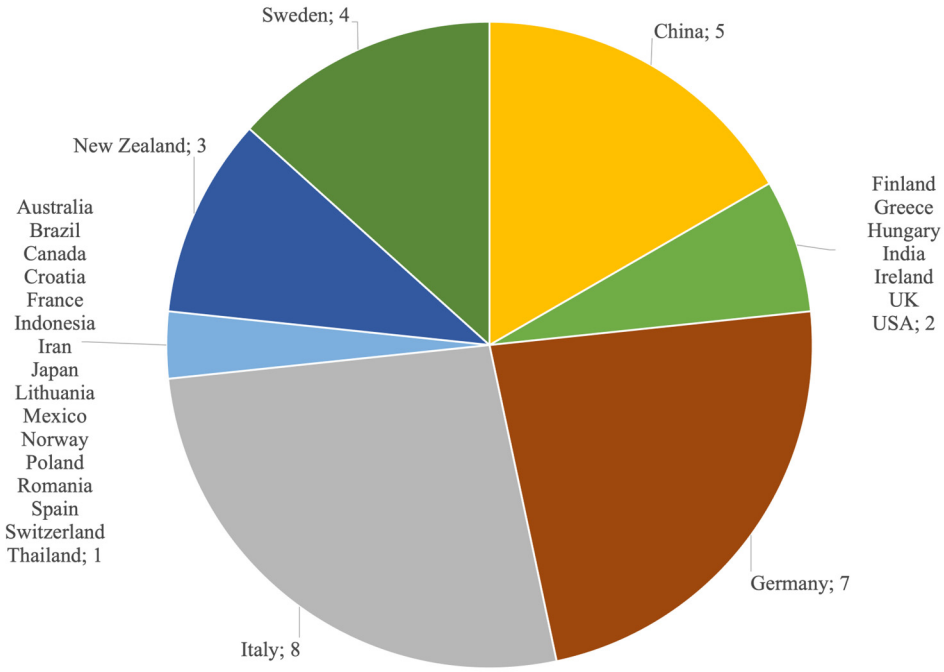

Figure 4. Graphic representation of the number of articles published by location (Country; Number of publications).

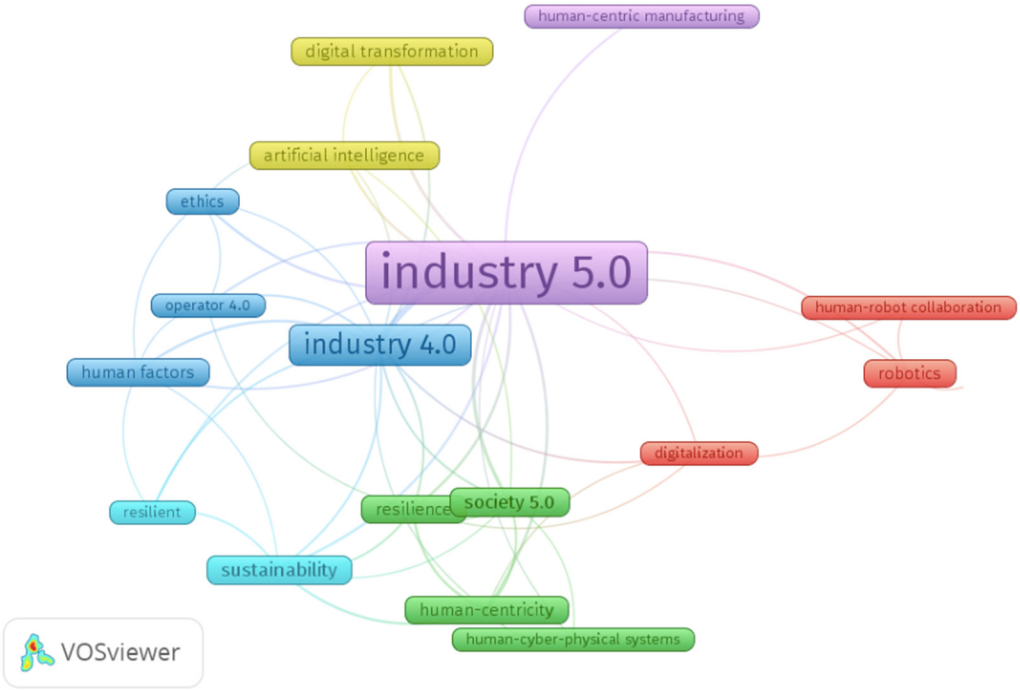

Figure 5. VOSviewer map of the keywords with high occurrence.

The keywords that had high occurrence were Industry 5.0, Industry 4.0, Robotics, Sustainability, Resilience, Digital Transformation, and Human-centricity, which are interconnected and linked to another, such as human-centric manufacturing, human-robot

collaboration, ethics, human-cyber-physical systems, society 5.0, human factors, resilient, among others. They are organized by six clusters, as represented in Figure 5 through different colours: Industry 5.0 as purple, Industry 4.0 as blue, Robotics as red, Digital transformation as yellow, Sustainability as turquoise, and, finally, Human-centricity as green. To guide the article toward data analysis and relevant information to answer the research questions, the results and discussion of the theme will be divided into three lines of investigation, grouping some of these clusters. The first line of research will be Industry 5.0 (including Industry 4.0, Human Factors, Resilient, and Sustainability); the second line of research will analyse the Technologies of Industry 5.0 (incorporating Digital transformation, Artificial Intelligence, Robotics, Human-robot collaboration, Digitalization); and, finally, the third line of research will focus on Human Centricity (including Resilience, Society 5.0, Human-centric manufacturing).

3. Review of Extracted Research

3.1. Industry 5.0—Concept, Ideology, and Proposals

The concept of Industry 5.0 was coined by the European Commission for the need to integrate European priorities with respect to social and environmental issues and drive companies and industries to evolve and become more sustainable, resilient, and human-centric [3,5]. Despite this concept, some research publications reveal that the concept of Industry 5.0 had been introduced by Michael Rada in social media in 2015, subsequently investigated by many researchers, and, finally, legitimized by the EC in 2021, so that the 2030 goals for the European Union could be achieved [12–14]. Industry 5.0 is an ideology of future industrial evolution aimed at using the creativity of human beings operating in combination with efficient, intelligent, and accurate systems [15]. These changes at the industrial level and in relation to technological innovations require rethinking the role of industries and their positioning and role in society [3].

With the recent COVID-19 pandemic crisis, it was possible to highlight the vulnerability of companies and industries to economic, technological, and social adversities. It was then necessary to reconsider the existing working approaches and methodologies, improving industries in terms of resistance and resilience, as well as sustainability and human factor centricity [16,17]. Furthermore, the turning point and starting point for the transition from Industry 4.0 to 5.0 focuses on changing the relationship between humans and intelligent systems [18]. While Industry 4.0 was only about automating processes with smart digital technologies with the aim of improving efficiency and optimizing industrial processes, neglecting the human factor, Industry 5.0 focuses on the synergy and pairing of humans and machines, where human desire and intention will prevail [19].

However, the concept of Industry 5.0 is evolving, and, therefore, there are diverse definitions elaborated by various industry practitioners and researchers [15]. The most consensual definition among researchers meets the one defined by the EC, whose industrial future is dependent on the consideration and weighting of human-centred, sustainable, and resilient production systems [18].

Focusing on sustainability, Industry 5.0 may be the first to be human-driven, which is based on the principle of industrial recycling, i.e., the 6R's policy: Recognize, Reconsider, Realize, Reduce, Reuse, and Recycle, so that it is possible to prevent waste and, at the same time, create/produce customized products with high quality [15]. However, there is a controversy associated with the ideology of Industry 5.0, i.e., how this strategy might contribute to sustainable development [20]. On the contrary, Industry 5.0 can be associated with the goal of bringing humans back into factories, where human and machines are paired and work in full collaboration in order to increase the efficiency of the production process through human cognitive capabilities (creativity and knowledge) and interconnecting them with the workflows of intelligent systems [15,18,19]. It is a similar perspective, in which professionals in industries and companies, information technicians, and researchers are required to focus and concentrate on human factors in the implementation of new technological systems of Industry 5.0 [15,18].

On the technological side, Industry 5.0 can be considered the era of the socially smart factory, or "Social Smart Industry", whose social business networks converge with people for seamless communication, namely, cyber-physical production systems interconnected with the human factor synergistically [15,18,21]. Additionally, Industry 5.0 is a human-centric solution, with humans and technologies, such as collaborative robots, working together hand in hand. Machines will be used for work-intensive or repetitive tasks, while humans will oversee personalization and critical thinking [15]. Another concept defines Industry 5.0 as a symmetric innovation that will be used for the next generation of global governance, whose goal is to create safe outputs for production by segregating automation systems [15].

Industry 5.0 involves again humans in global industrial environments and intends to empower them through the incorporation of innovative technologies. The main idea of this strategy is the convergence of several aspects of human centrality, systems resilience, and sustainability, through industrial harmonization between machines and humans [18]. However, the ideologies and concepts of Industry 5.0 are open, evolving, and expansive, but always based on the three fundamental pillars described above. Thus, the goal of Industry 5.0 is to place the well-being of workers at the centre of production processes, maintaining a balance between humans and machine systems, and aggregating the ideals of resilience and sustainable development at ecological, economic, and social levels.

3.2. Industry 5.0 Technologies

Industry 4.0 has led to rapid technological advances and high industrial performance [22]. In parallel, the concept of Industry 5.0 has flourished, with the intention to integrate physical and virtual spaces through human-centricity with technology, namely, the application of Internet of Things (IoT), robots, and augmented reality to achieve a smart industry and society of digital innovation [23]. Interactivity between humans and machines is considered one of the key differences between Industry 4.0 and 5.0, as when this interaction increases, there is an empowerment of operators' expression in how products and services are personalized, creating synergistic relationships between technological and social systems [22,23].

Industry 5.0 requires human beings to undergo a socio-technical evolution, i.e., a paradigm shift in the role of the operator as the central focus of manufacturing and production systems through intelligent strategies and approaches underpinned by advanced information and communication technologies [22]. Industry 5.0 ideology can be applied to cyber-physical production systems (CPPS), from their conceptualization, learning, and integration [24], and including a human perspective [25], to data interoperability and information sharing [26] using 5G and 6G networks [27]; automatic identification and traceability (Auto-ID) systems [28]; Artificial Intelligence (AI)-based systems for work assistance, organization, and supervision [29]; industrial simulation [30]; user application of Augmented Reality systems [31,32]; and also collaborative robots or cobots to achieve intelligent manufacturing systems [33,34].

The introduction of robotics in production systems can increase productivity, but also increase the well-being of workers, as well as improve the health and safety conditions of workplaces [35,36]. Robots and their human-robot collaborative environments leverage individual and technological capabilities together, making it possible to overcome limitations in the execution of awkward, repetitive, and potentially harmful tasks and operations, improving the workplace, as well as the repeatability and reliability of processes [35]. Thus, collaborative robots support and reduce low-value-added operations for operators, while workers' potential is harnessed for advanced operations and tasks that require greater sensitivity, mental processes, rapid self-adaptation [22,35], customization, and critical thinking [31]. In scenarios of cooperative or collaborative sharing of workspaces between humans and robots, it is necessary to assess human factors before, during, and after the whole human-robot interaction, so that analysis and evaluation of working conditions can be done [31].

A particularity of the use of robots is the development of the Digital Twin (DT), which represents a high-fidelity, virtual, physical entity with real-time communication [30,37]. These DT systems are technological advances identified for Industry 5.0 that, together with simulation systems, allow production optimization and, at the same time, perform operational safety tests [38]. Moreover, although DTs are technological models focused on connectivity and modelling of production systems [37], they can be used to combat educational inequality by providing learning and training through tele-operability [39], and they can be included in educational systems [38]. Interactive productive systems with robots can also be used to create training and learning environments [40].

With the introduction of Industry 5.0 and human-centric production systems, human-robot interactions raise questions regarding safety [41] and ethical issues [29]. Safety requirements are higher, and, therefore, safety strategies need to be adopted to achieve higher degrees of reliability and production flexibility through dynamic and synergistic measures (from both human and robotic perspectives) [41]. Ethical issues concern the use of autonomous intelligent systems, such as robots and artificial intelligence, and should have been taken into consideration from the very beginning of the design processes of new digital production systems [29,42].

However, companies and industries must put human beings at the centre of production processes by developing and applying reliable technologies that provide better working environments and improved well-being for workers [43]. Thus, it is important to retain and apply the organizational memory of past experiences and operators so that successful experiences can be reused [44], making it essential to understand the experience and knowledge of operators during work operations [43].

For companies and industries to achieve the ideologies and benefits of Industry 5.0, they would need to draw on and make use of Industry 4.0 digital technologies, such as cyber-physical systems; big data technologies; and human-machine interaction technologies, such as artificial intelligence, digital twins, and collaborative robots [28]. The European Commission has identified six guidelines to be considered as Industry 5.0 technologies: individualized human-machine interaction, intelligent bio-inspired technologies, simulation and digital twins, data transmission, storage and analysis technologies, artificial intelligence, and technologies for ecological autonomy [28].

3.3. Human-Centricity in Future Industrial Environments

Prior to digitalization and automation, human beings were responsible for ensuring manual jobs, including repetitive and physically demanding operations. However, with the adoption of digital technologies, humans were considered a weak point within the industry, as they were prone to errors and defects; therefore, they were gradually replaced by technology [45]. In contrast, the human factor is a central resource in most companies and industries; hence, the shift to a human-centred strategy, where human needs and interests are placed at the centre of production processes [3]. It evolves from a technology-centred approach to a human-centred approach, where human beings will use the power and precision of technology as a resource that can be adaptable to the needs and diversity of industrial workers. Thus, the flexibility and creativity of operators can be preserved and empower them to overcome the adversities and limitations imposed by technology [3,45].

Industry focused on worker well-being is prioritized and ensured by developing technologies that create rewarding and motivating work environments that match users' needs [46], but mainly industries with safe and inclusive work environments that focus on workers' physical and mental health, well-being, autonomy, privacy, and dignity [3].

Other strategies to improve operator well-being include providing a diversity of work schedule times; job rotation; considering the demands of getting the job done and the needs and qualifications of operators; and ergonomic workplace exposure [43]. On the contrary, human-centeredness can be accomplished by involving all production system stakeholders in the processes of conception, design, and innovation [46,47]; in system planning and control processes [48]; and in product and process design [49]. The application of lean

management tools to put humans at the centre of production processes has also been studied [50], such as the application of human centricity in the SMED tool (H-SMED) [51].

In the future, industrial workers need to shift from technological to socio-technological productive systems and, consequently, continue to acquire, upgrade, and retrain their knowledge, skills, and qualifications to create better career opportunities, balance work and personal life, and enhance job development and polarization [3,52]. In parallel with sustainable, resilient, and human-centred transformation, the operators of the future need to be prepared and trained, so that they can take an active role in production systems and promote the success of the industrial digital transformation [53]. Industry 5.0 will have a major impact on the collaboration between humans and smart technologies, as well as on the technological and social management of future production systems; therefore, continuous training is needed to ensure future skilled labour through the development of multifaceted human skills and digital education [54].

4. Discussion

4.1. Industry 5.0—Industrial Perspective and in Society

To boost the development of individual well-being and sustainable economic growth, Industry 5.0 has emerged with the aim of making production human-centric, putting the well-being of the worker at the centre of industrial smart production processes [55,56]. The fifth industrial revolution associated with Industry 5.0 determines the joint work between operators and machines to increase the productivity and efficiency of companies and industries [57]. Operationalizing and putting into practice Industry 5.0 is a future ideology, as industries are still in the implementation phase of Industry 4.0. However, it can be said that the two will coexist, that is, the technological development of Industry 4.0 will be made with the ideologies of I5.0 regarding human centering.

Industry 5.0 is also characterized by high precision and low-cost mass customization [34], introducing sustainable and resilient thinking in a digital transformation with human-centricity and bio-economic ideals for a future society, Society 5.0 [58]. Society and Industry 5.0 require companies and industries capable of establishing active relationships between humans and digital technologies that target workers, becoming socially automated [59]. There are numerous definitions and concepts for Industry 5.0, and their interpretation can distinguish key points that differentiate them. Most of them focus on the socio-technological era, while there are others that focus only on industrial transformation [18].

4.2. Human Centricity with Industry 5.0 Technologies

Human-centred production systems are a recent and controversial topic in need of clarification and discussion. However, the concept draws on ongoing human-focused research, such as Ergonomics, Operator 4.0, and Human-Robot Collaboration [56]. Industrial production and manufacturing will move towards Industry 5.0, which will be supported by collaborative robots [60], artificial intelligence, and cognitive computing technologies [57]. Human-Robot Interaction is a technological enabler for the transfer from digital system-centric to operator-centric production, in a digital production environment that considers human and robotic characteristics equally [36]. For the interaction to be beneficial and provide advantages for production systems, it is necessary to optimize the use of available resources, both humans and robots [36]. Another advantage of using these collaborative systems is the reduction of stressful and repetitive operations that can expose the worker to potential health and safety risks, without the need to invest in other expensive and sophisticated digital equipment [35]. Augmented Reality can be used to enhance human and robot cognitive capabilities by integrating humans into production systems in real time and dynamically [41]. Moreover, the evaluation of the impact of Human-Robot Interaction is difficult to elaborate and restrictive because classical tools are based on kinematic and static aspects, omitting relevant information. Therefore, alternatives for Human-Robot Interaction assessment have been currently studied and used through computational and sensor systems that allow for a more complex, advanced, and dynamic analysis [31].

To achieve social, environmental, and economic sustainability and resilience in companies and industries, engineering education will have to be reviewed and redesigned to train future engineers with technological, data, and knowledge fluency to make industries more resilient, sustainable, and human-centric in the era of Industry 5.0 [61]. The future workforce should have the experience and knowledge to distinguish and understand the different production systems to make the most appropriate decisions among the different ways of working: only human effort, only technological effort, or a collaboration between the two. Thus, engineering education should focus on human-technology interaction, especially on the different forms of communication and collaboration with future cyber-physical systems [61]. In addition, human-assisted learning strategies can be applied to monitor and control automated additive manufacturing systems, as well as manufacturing error detection systems [62,63].

4.3. Operator of Industry 5.0

The ideology of Industry 4.0 by automated and highly efficient production systems has put workers' welfare in the background. As a consequence, it can be said that in Industry 4.0, the human factor is neglected. In contrast, the Industry 5.0 operator should strategically use technology to improve the work environment's quality. Thus, this idea meets the centrality of the human being in production processes, where technology supports the human being. Hence, a synergistic effect is achieved regarding the interaction of humans and robots, where the human factor can collaborate, integrate, and deal with new digital technologies [45]. In parallel with the introduction of Industry 5.0, the concept of the Operator 5.0 has also emerged, representing the Operator 4.0 of the future, that is, more resilient against the adversities encountered in digital industrial environments, the Resilient Operator 5.0 [64]. The Operator 5.0 can be divided according to its purpose, i.e., a self-resilient operator that has evolved in the face of its inherent weaknesses and adversities, and an operator focused on system resilience, i.e., resilient human-machine systems [15]. However, it is essential to understand the complexity of future industrial production systems that are highly volatile and imply more complex and multi-faceted decision making for the worker. Therefore, the operators of the future must be empowered with human-centric technology and adequate education to be able to remain in control of production and manufacturing systems [53]. As such, it becomes important to empower workers of different ages and with different biographies, as they are the focus of human workforce sustainability [53], especially employed ageing workers who are associated with high-intensity work [65].

4.4. Challenges, Limitations, and Future Agenda

In relation to the research process, the limitations of this study are related to the limited number of real industrial cases of application of concepts and ideologies of Industry 5.0. Moreover, given the actuality, urgency, and emergency of the human centricity theme, it would be important not to restrict the scientific data of the research exclusively to English. Thus, as future research perspectives, it would be crucial to use publications in different languages to provide new and valuable insights in this study. On the contrary, a challenge for the future will be to conduct studies in laboratory settings to accelerate the research process. However, it should be noted that these experiments may lead to results that are out of touch with reality.

In moving towards human-centric production and manufacturing, there are several challenges, limitations, and opportunities from social, technological, and ethical perspectives. Regarding the ethical concerns, already in Industry 4.0, ethical issues were arising. However, just as Industry 5.0 follows on from and co-exists in parallel with Industry 4.0, ethical problems also overlap. In this case, of even greater relevance due to human centralization, the human being is placed in a position where ethical issues are more pertinent. In industrial and automated environments with digital technologies, ethical, health, and safety issues are very important, and, because of that, a hot topic for future studies exists.

Shifting from a strategy of high industrial performance (Industry 4.0) to a strategy of human centricity (Industry 5.0), there will have to be a balanced equilibrium between performance, technologies (digitalization), and human well-being. Despite human limitations, there is a window of opportunity for improvement and development, namely, leveraging human-machine interactions and developing human skills and capabilities for this new human-digital era. One of the challenges centres on acceptance and trust in technology, as for human-centric work environments, the technologies to be used need to be reliable, intelligent, and friendly to work with, while always maintaining privacy boundaries. Robot-Human Interaction becomes a limitation and a challenge for the future, as there is a need for collaborative and cooperative technologies that help the operator and do not replace him, and that is customizable according to each operator's individual characteristics and skills. In addition, these systems need to be transparent, i.e., share all the information and data they use for their functioning in performing tasks and operations and their decision making.

On the contrary, there are opportunities that can be achieved when overcoming some challenges imposed by the era of human centricity, such as changes in work dynamics, both at the team level and interaction with technologies, and the capacity and acceptance for lifelong learning, for a constant and evolutionary adaptation of human beings to emerging technological advances. Another major limitation of conducting studies in industrial environments is the difficulty of openness and acceptance of operators and top management to new ideas and technologies.

As a future research agenda, it is necessary to act and create real and achievable strategies and methodologies to put the human factor at the centre of production, without neglecting the human factor and implementing the ideologies of Industry 5.0. It is perhaps too early to speak of Industry 6.0 when Industry 5.0 is in its early stages of development. It is important to note that one of the pillars of Industry 5.0, according to the European Commission, is sustainability, which encompasses the environmental/ecological aspects regarding the limits of our planet. However, if Industry 5.0 is human-oriented, will Industry 6.0 be devoted to the environmental-oriented? For now, the goal of Industry 5.0 is to place the well-being of workers at the centre of industries and companies, maintaining a balance between human-machine systems and developing a resilient and sustainable work environment at ecological, economic, and social levels. Figure 6 shows our vision of a schematic representation of how the human factor, i.e., Operator 5.0, is placed in the control of production systems, where the well-being of the workers is a high priority. Furthermore, the centralization of the human being through the aid of digital and robotic technologies in sustainable and resilient smart factories in the age of Industry 5.0 is represented.

Figure 6. Schematic representation of the human-centricity at the control of smart factories in the era of Industry 5.0.

5. Conclusions

Industry 5.0 follows Industry 4.0 with the ideology of placing the human being at the centre of industrial production processes. Thus, the transformation will occur from production systems oriented towards technological advance and high productivity to production systems oriented towards the human being and high customization. As such, the human being is no longer commanded by technology and becomes its controller, using it to his advantage. However, the concept of Industry 5.0 is not yet fully accepted by companies and industries, but it is driven by researchers because, nowadays, the industrial reality faces challenges still inherent to Industry 4.0 and the digitalization era. Thus, up to this point, the idea of the concept of Industry 5.0 is the centralization of humans in production systems, but the studies carried out focus a lot on technological advances and the development of technologies for this purpose. It can be concluded that there are not many studies that prove this human centralization, but research has been done in the sense of applying digital technologies for human benefit in industrial environments. It can be concluded, then, that research involving the ideologies and concepts of Industry 5.0 is human-oriented, specifically to increase the well-being, health, and safety of humans.

Moreover, it could be said that the digital technologies of Industry 4.0 will be applied and used as Industry 5.0 technologies, only empowering and manipulating them to create value for the human factor. With the introduction of Industry 5.0 in smart manufacturing systems, the operator will also have to evolve into a resilient and digital operator, always taking into consideration the existing human capital in today's industrial reality, specifically the ageing workforce.

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