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Industry 5.0 – Past, Present, and Near Future

João Barata[a,*], Ina Kayser[b]

[a]University of Coimbra, CISUC, Department of Informatics Engineering, P-3030 290 Coimbra, Portugal.
[b]IST University of Applied Sciences, Department of Communication & Business, Erkrather Straße 220a-c, 40233 Düsseldorf, Germany.

Abstract

The industrial transformation is sociotechnical. Industry 5.0 is one of the recent terms to describe this phenomenon, defined as a humanized vision of technological transformations in industry, balancing the current and future needs of the workers and society with the sustainable optimization of energy consumption, materials processing, and product lifecycles. This paper presents a tertiary study of thirty-two literature reviews on Industry 5.0, supported by a bibliometric analysis in the Scopus database. The results show three stages of Industry 5.0 research since 2018, starting with the Industry 4.0 separation. The latest priority is to deploy circular manufacturing strategies supported by human-friendly digitalization capable of anticipating and acting proactively on impacts. Therefore, Industry 5.0 is future-oriented and cross-sectoral, (interactively) diverging from the original configuration of Industry 4.0. For theory, we highlight the findings of recent literature reviews, clarifying the landscape of Industry 5.0 research and suggesting future developments. For practice, this paper presents examples of societal priorities that industries should consider in their digital transformation investments, as crucial as improving economic competitiveness.

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Keywords: Industry 5.0; bibliometric analysis; tertiary study; research agenda.

* Corresponding author.
E-mail address: barata@dei.uc.pt

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1. Introduction

Industry 4.0 started as a policy-driven transformation of manufacturing using digital technologies [36]. The term appeared in 2011 and became integrated into the high-tech strategy issued by the German government [36]. The technological portfolio of Industry 4.0 is vast and includes cloud computing, the Internet of things (IoT), artificial intelligence, autonomous robots, augmented reality, or blockchain, aiming to create smart factories [19]. A decade of Industry 4.0 research revealed many advances in manufacturing connectivity and created the foundations for Industry 5.0 [31,19], "dictated primarily by the need to expose man's role in cyber-physical systems" [12].

There is now a future-oriented and societal-driven transformation of manufacturing. It also includes policy priorities, like the outstanding efforts made by the European Union to advance Industry 5,0, simultaneously addressing: "an economy that works for people", "European Green Deal", and "Europe fit for the digital age" [10]. Nevertheless, academia has had a vital role since the early stages of Industry 5.0. The industry is taking the first steps, confirmed by their recent roundtable on 27 April 2022 [10], stressing the disruptions faced by our society and the need to avoid going back to unsustainable practices. More importantly, the experts' conclusions point to the unique importance of cross-sectoral approaches, resilience, governance, and shifting from the competitiveness priority of Industry 4.0 to the "digitalization with a purpose" (report available in [10]).

Recent systematic literature reviews on Industry 5.0 provided inspiration and a starting point for our research. These examples include a bibliometric analysis in Web of Science and a review of 22 Industry 5.0-related papers [12], the comprehensive evaluation of 196 abstracts [1], or the review of [22] based on 92 papers published in Scopus, between 2015 and 2021. However, a review of literature reviews (tertiary study) is still absent in the Industry 5.0 literature. As advised by [22], "Industry 5.0 will continue to grow, at least in the short term (…[and]) it will be interesting to follow [its…] future evolutionary trajectory". Therefore, the research objectives addressed in this paper are *to assess the evolution of Industry 5.0 literature since its appearance, clarify the current research landscape, and suggest guidelines for future work*.

Our method follows two stages: (1) a bibliometric analysis in Scopus extending the work of [22] with 277 recent publications (adding 185 published between 2021 and 2022) and (2) a tertiary study. We followed recommendations for performing systematic literature reviews in information systems research [29]. After defining the review purpose, protocol, and work preparation by the two reviewers, we evaluated the 277 publications indexed in Scopus since 2018, using VOSViewer [9] - stage 1 - bibliometric analysis. The keyword "Industry 5.0" was used, excluding three unrelated publications before 2018. This phase allowed us to understand the different eras of Industry 5.0 and the articles' characteristics (e.g., authors, location). Next, we assessed reviews published exclusively in journals (initial set of 184 articles) – stage 2. The selection of literature reviews was made from two samples: automatic selection according to Scopus classification (type = review) and a manual analysis made by the two authors in the list of journal reviews, providing 16 and 53 papers, respectively. After removing duplicates and performing content analysis, we reached 32 papers. We excluded publications that did not provide a distinct conceptualization of Industry 5.0 and/or only briefly approached the term and/or did not have a scientific approach (e.g., a comment).

The rest of this paper is organized as follows. Section 2 presents the bibliometric assessment. Next, section 3 presents the tertiary study of 32 recent literature reviews (appendix A) on Industry 5.0. The discussion proceeds in section 4, and the paper closes with the main conclusions in section 6.

2. Bibliometric analysis of Industry 5.0

2.1. Network evolution – the three stages of Industry 5.0 research

Four main clusters were identified in the aggregated analysis (no time restriction). The first cluster integrates the most fundamental keywords of Industry 5.0, namely, Industry 4.0, manufacturing, personalization, digital transformation, the vision of society 5.0, and sustainability. The second cluster aggregates the future workplace shared by humans and machines (e.g., operator 4.0) and a recent trend related to supply chain resilience. The third highlights the importance of digital twins (e.g., for simulation, optimization, and prediction of physical objects' behavior), and the most numerous cluster (the fourth) shows essential technologies (e.g., blockchain, IoT, augmented reality, 5G, and 6G). Fig. 1 illustrates how research has evolved since 2018, according to three stages.

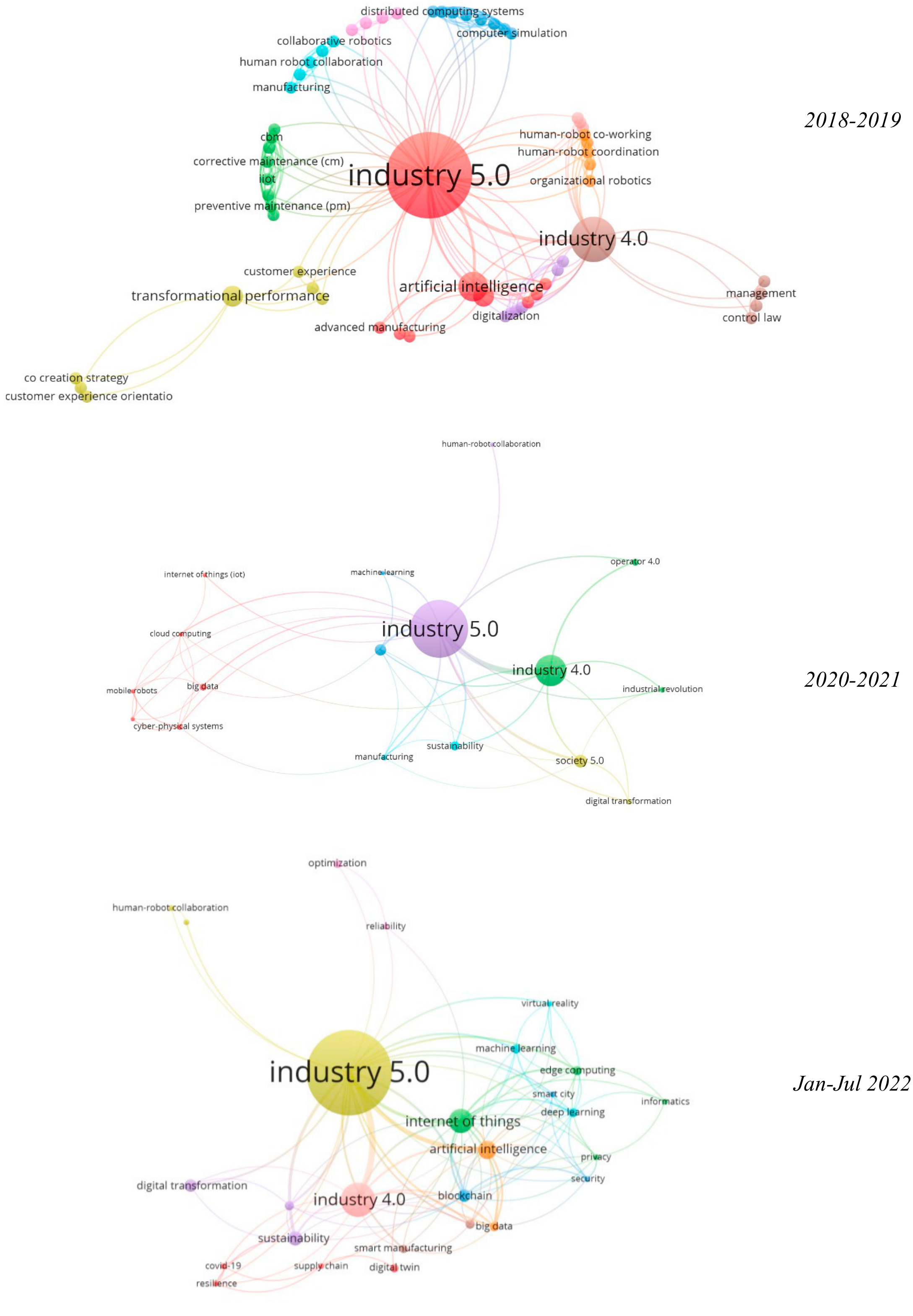

Fig. 1. The three stages of Industry 5.0 research (2018-2022).

The first stage (2018-2019 – digital transformation consequences) helps understanding how Industry 4.0 shifted to the 5.0 perspective. The human-machine interaction (orange cluster) and technologies (red) provide the initial links, paving the way for more “social” clusters of digitalization like customer experience. The next group of papers (2020-2021 – the societal priorities for digital transformation) already include sustainability, maintaining a technological background migrating from Industry 4.0, and showing the links to operator 4.0 and society 5.0. The most recent research (since 2022) presents more complex scenarios like smart cities and digital twin technology. The aspects of security (and related technologies like blockchain) are also found in this set of papers. Compared to the birth of Industry 5.0, containing more general terms and two most significant nodes (Industry 4.0 and Industry 5.0), the third stage opens new avenues for synergies between technological advances and better futures.

2.2. An overview of search results in journals

The number and impact of Industry 5.0 publications are increasing at an exponential rate (Fig. 2).

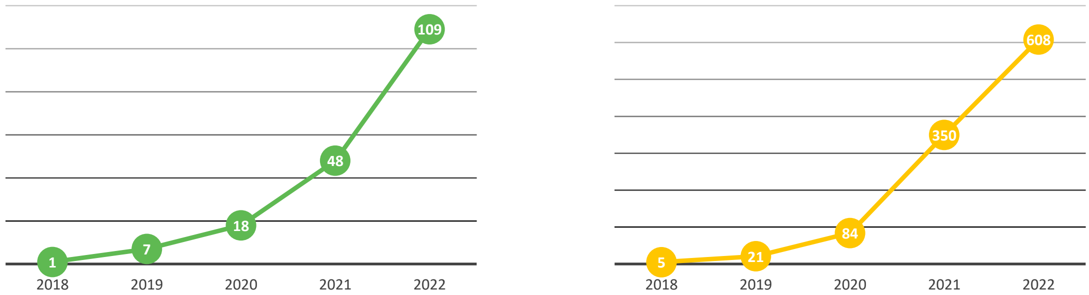

Fig. 2. Number of journal papers (on the left) and citations (on the right) indexed in Scopus for Industry 5.0 (2018-July 2022).

Fig. 2 confirms the importance of this topic, more than doubling the number of contributions in Scopus each year and revealing an h-index of 15. Fig. 3 depicts the number of papers per country.

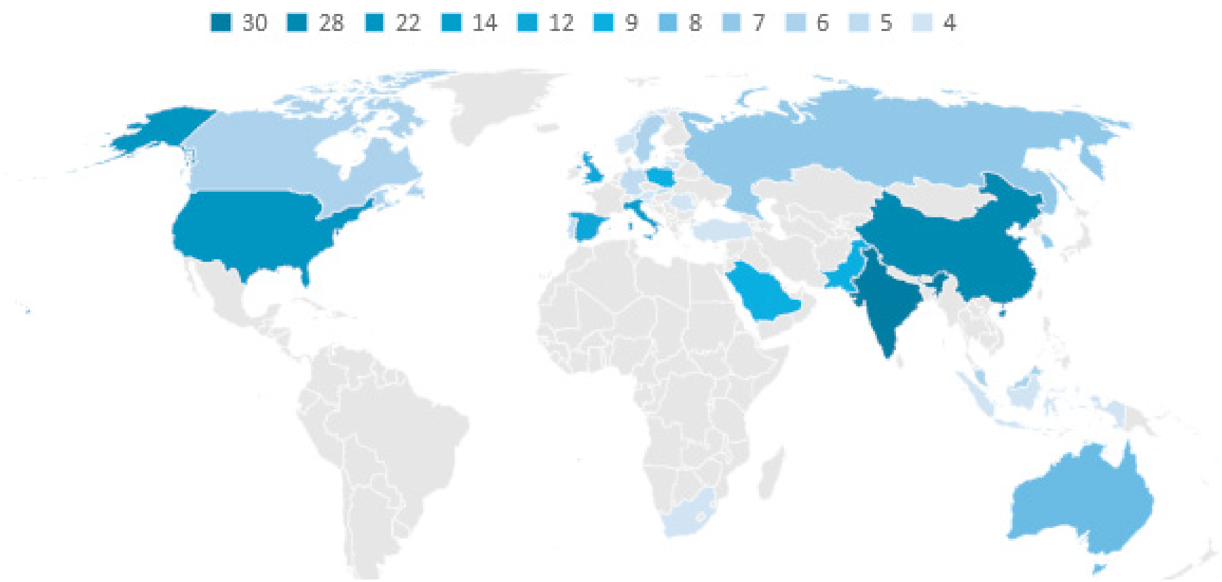

Fig. 3. Country map for Industry 5.0 journal publications, indexed in Scopus since 2018.

The top three countries include India, China, and the United States of America, followed by a few European countries (Italy, Spain, United Kingdom). South Asia (Pakistan), the middle east (Saudi Arabia), and Australia complete the regions with at least eight publications. The interest in the topic is global, but it can also be noticed the prevalence of the most industrialized countries and the need for more advances in transition economies in Africa (only South Africa presents at least four papers, although Egypt in the northeast or Morocco can be found in the list with two papers each), or South/Central America (e.g., Mexico or Brazil with less than three papers).

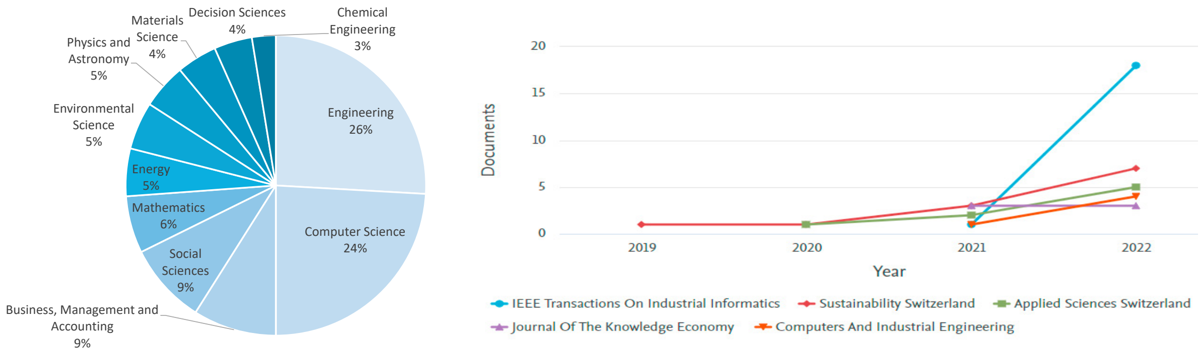

Fig. 4. Area of knowledge (on the left) and top journal publications in Industry 5.0.

The areas of engineering and computer science represent 50% of the sample (Fig. 4). Social and economic sciences follow in the list with almost 20%, but the topic is transversal to fields like energy, mathematics, materials, or the environment. The top outlets publishing Industry 5.0 research are leaded by IEEE Transactions on Industrial Informatics (7), two multidisciplinary open access publications (Sustainability and Applied Sciences), Journal of the Knowledge Economy, and Computers and Industrial Engineering. Important information systems journals like the Journal of Industrial Information Integration or Information Systems Frontiers are also aware of Industry 5.0 emergence. The most active funders of Industry 5.0 research are the European Union structures (e.g., European Commission with five or Horizon 2020 with six) and the National Natural Science Foundation of China (six papers). However, the list of funders includes dozens of countries around the globe, starting with the Slovak Republic with four studies, completing the top three. The descriptive analysis of the 184 journal publications indexed in Scopus since 2018 confirmed (1) the continuous growth of Industry 5.0, (2) the worldwide interest, mostly in more advanced economies struggling with sustainability concerns, and (3) the focus on computing and engineering, derived from its close relationship with Industry 4.0.

3. A review of Industry 5.0 literature reviews

The focus of the meta-reviewed articles is heterogeneous. Nonetheless, our research discloses that most articles center around (1) a broader perspective on global issues such as the sustainability and health care or (2) industry and technology development to solve these global issues. Moreover, we reviewed two articles that shed light on education-related topics. Nonetheless, the articles we reviewed show different views regarding the Industry 5.0 terminology and the question of whether Industry 5.0 is a new paradigm or an advancement of Industry 4.0, for example, as the answer to a changed customer and purchasing behavior triggered by personalization in Industry 4.0.

Rowan et al. [38], for example, argue that innovation in peatlands will be driven by digital solutions that include process automation, data analysis and processing, control and management systems. They present a rather human-centric consideration of Industry 5.0, in which these technological-driven activities align with the main principles of Industry 5.0, which puts people at the center, and with many of the UN's Sustainable Development Goals [38]. Rowan [39] also promotes a human-centric approach to Industry 5.0, in more detail the use of artificial intelligence (AI) and human-computer interfaces to solve global food chain issues. Moreover, Rowan [39] presents the concept of social marketing at the “interface of human and natural systems and their interconnected dynamic forces as a powerful means of influencing behaviors for the accorded transformation and betterment of individuals, communities, society and the planet" [39]. In their more specific view of Industry 5.0, they instead stress the aspects of mass personalization, increased human-computer interaction as a means for social problem solving, and advancement from Industry 4.0 to Industry 5.0 [17]. Dhawan et al. [7] focus on technological elements such as transport optimization, data and information sharing, and collaboration for transport decarbonization to transition the current 4.0-construction industry to a 5.0 industry in New Zealand [7]. Hence, they refer more to technological advancements regarding the achievement of sustainability goals.

Orea-Giner et al. [30] explore the relationship between clients' emotions and sentiments created by the interaction with hotel robots and the possible effect on a hotel's rating. In their view, Industry 5.0 is the "enhanced experience of the final customer by applying the different tools available considering artificial intelligence (AI) and robotics" [30]. Kaasinen et al. [16] foster the focus on intelligence and resilience regarding next-generation manufacturing systems and human operators. They present three core elements of future Industry 5.0 factories: human-centricity, sustainability, and resilience [16], aligned with the European vision [10]. The authors present a design approach in which human operators and smart machines form collaborative teams [16]. In a different line of research, Popov et al. [35] establish a high-level link between Industry 5.0 and healthcare describing it as a trajectory. Coronado et al. [6] present Industry 5.0 as a paradigm change to overcome societal and planetary challenges resulting from prior industrial revolutions by promoting the idea of human-centered smart environments and human-robot interaction. Moreover, like Kaasinen et al. [16], they refer to the conceptualization of the European Union of Industry 5.0 as means to reach human-centered, sustainable, and resilient industries [10,6]. Additionally, they center the idea of Industry 5.0 as value-driven scenario around the manufacturing sector and summarize the more human-centric considerations under the term "Society 5.0" [6]. Among others, Carayannis et al. [5] explicitly distinguish between the concepts of Industry 5.0 and Society 5.0. In their commonly accepted view, Society 5.0 is a human-centered "mutual societal infrastructure for prosperity based on advanced service platforms", whereas Industry 5.0 is a "renewed human centric industrial architype" that restructures industrial production processes [5]. As enabling technologies for this transformation, artificial intelligence, blockchain, and IoT are presented [5]. Maier et al. [23] analogously promote the term "Society 5.0" for the more human-centered approach to production, rather than anchoring this under the broader concept of Industry 5.0. Duggal et al. [8] present a roadmap with two main phases: synergetic co-production and bio-upgradation. They define Industry 5.0 as a concept where robotic assistance and the human workforce work together seamlessly with the human component while simultaneously stressing the importance of personalization and customization, especially personalized bioengineering [8]. Shahbakhsh et al. [41] identify human-robot co-operation and personalization as change factors in Industry 5.0. According to Maddikunta et al. [21], Industry 5.0 can lead to applications such as intelligent healthcare, cloud manufacturing or the integration of mass-customization into supply chain management [21], in deeper collaboration between humans and machines. Fatima et al. [11] present a review on the maximization of benefits through human–machine interaction regarding production plant and warehouse automation. They consider Industry 5.0 an evolution of Industry 4.0 "in which human creativity will collaborate with smart systems, such as robots and machines, especially in the production plants and warehouse systems" to make "production plants and industries faster, efficient, and more scalable." [11]. Paul et al. [33] view Industry 5.0 as an extension of Industry 4.0, with a stronger focus on human-centered computer interactions. Pereira Guimarães et al. [34] also consider Industry 5.0 as an extension of Industry 4.0 with an increased focus on personalization and human-computer interaction in their critical review regarding the cutting of temperature measurement in production processes.

Especially technological safety and security, legal issues concerning human-robot-interaction and artificial intelligence [44,42], as well as human adaption to Industry 5.0 [41,27] are considered major challenges. The last topic is taken up by two articles that focus on education and the necessary skills and competencies for workers to adapt to the evolving Industry 5.0 environment [13] and changes to the university landscape [5].

There is a continuum in the technological advances in manufacturing, and several authors have studied Industry 5.0 and Industry 4.0 side-by-side. For example, detailing the extensive technological elements shared by Industry 4.0 and 5.0 [2] or including a section in their papers dedicated to the prospects of more personalized manufacturing, combining humans and machines in more humanized environments [19]. Other examples include Ergonomics 4.0 and 5.0 [33] adopting cyber physical systems, including its structures, technologies, or the operator 4.0 in deeper collaboration with robots. The digital twins, human modeling methods, and real-time monitoring enabled by

Industry 4.0 are important tools to protect humans and ensure performance [33] towards a humancentric Industry 5.0. Other Industry 5.0 reviews point to the importance of personalization and the role of technology in societal needs (e.g., green housing [17]), the synergies with Society 5.0 [37], cognition of robots and digital twins [28], and the use of technology fostering societal development goals and sustainable engineering [25]. Both the "4.0" and "5.0" concepts are relevant and exploring their synergies can contribute to knowledge accumulation in the ongoing industrial transformations.

4. Discussion and near future recommendations for Industry 5.0

The principal streams in the literature on Industry 5.0 are future-oriented and cross-sectoral. Whereas Industry 4.0 seems to have a particular technology-oriented purpose, i.e., the use of digital technologies to solve particular manufacturing problems and productivity improvements, Industry 5.0 pursues a more holistic purpose with not only a more customer-centric [44] but a more human-centric view in general [41,38]. In Industry 5.0, digitalization is used to answer broader questions regarding environmental, energy, and social challenges. It is hence the integration of the technological determinants that shaped Industry 4.0 into the larger context of humanity, spanning the boundaries of the factory floor. One can therefore argue that Industry 5.0 is not technology-driven but value-driven [45]. Industry 5.0 perceives, on the one hand, the human being as a consumer who expects personalized products on a broad scale. On the other hand, there is the appropriately skilled human being as a worker who will interact with robots to make this possible. A more global view describes humans as an element in a set of global challenges that must be solved for the survival of the human species. Industry 5.0 is seen here as a paradigm shift that allows this integration of industry and production and solving global crises through value orientation.

Ethical use of technology is not an option in Industry 5.0 [16], and essential research lines are already open for the improved well-being of human workers. Nevertheless, using artificial intelligence for decision support in more digitalized factories should adopt sustainability criteria by design (e.g., supplier selection may use criteria to minimize transport or prefer suppliers that also contribute to carbon reduction). How artificial intelligence can be used to minimize waste (e.g., predict product demand) and make fair manufacturing decisions is an essential research line. Moreover, more specific key performance indicators (KPI) must be developed for Industry 5.0. A societal-friendly industry needs to be able to disclose best practices and prove the adoption of responsible processes. The recent European priority for energy saving and responsible water use in industrial settings are two examples of practices requiring trustable KPIs. Blockchain technology and data science advances in this area are promising.

The regulatory space of Industry 5.0 is vast. On the one hand, voluntary regulations (e.g., IoT interoperability standards) in Industry 4.0 will continue to be relevant, ensuring data sharing and communication between machines and/or humans. On the other hand, legal (enforced) regulations affecting specific resources, work practices, or resource use are also relevant since the early stages of diagnosis or requirements elicitation for Industry 5.0 projects. For example, several segments in the clothing supply chain (e.g., raw materials, fiber processing, production, transport, distribution, or recycling) should implement (and disclose) traceability, circularity, and waste reductions to comply with the new regulations of digital product passports. The digitalization challenge of "5.0" is regulatory, cross-sectoral, and cultural, influencing how industries invest and how consumers make informed choices.

More use cases of Industry 5.0 are needed to guide the practitioners, opening opportunities for additional literature reviews. For example, how to use technology to create products protecting the human during the production process (e.g., wearables) and product use (e.g., autonomous vehicles, medical devices) or use cases for data-driven environmental footprint reduction should be on the agenda of researchers. Industry 5.0 is a pillar of future smart cities [15]. For example, using intelligent systems to reuse smart city wastes, reach zero carbon impact in production or transport, and offer the best smart workplaces for the citizens.

Literature reviews on Industry 5.0 safety and security or regulatory issues (e.g., standardization, support for legal initiatives) are still scarce. Society 5.0 will only be complete if Industry 5.0 achieves the same level of human-centric performance. Therefore, future systematic literature reviews can strengthen the pillars of Industry 5.0. For example, how to improve the resilience of specific regional economies and manufacturing processes, review of technologies that may support sustainable policies (e.g., responsible use of water), and meta-analysis to assess the results of specific solutions for the workers or external stakeholders. The impacts of transformation are central to "5.0" research.

Industry 5.0 research lines include the enhanced use of technology for human-related concerns (e.g., healthcare, ergonomics, worker protection, cobot operation) and the transformation to more sustainable factories. Additional research is necessary for the viewpoints of Industry 5.0 as (1) the assessment of technology sustainability [5], (2) the impact analysis of technology transformations, (3) the increase of competitiveness via sustainability improvements driven by technology, and (4) the use of technology to eliminate physical resources depletion and assist resource changes (e.g., decarbonization).

It will be crucial to involve more developing countries to make Industry 5.0 an impactful initiative; technology shaping better futures will not have a future if it stays concentrated in the northern hemisphere, as shown in Fig. 3. Although understandably, more polluting societies have a great share of the problem side, they will need to cooperate globally on the solutions. Examples of future studies include digital transformation to support circular manufacturing, simultaneously promoting responsible work practices and assisting the sustainable development of emerging economies. Additionally, cross-sectoral supply chain resilience can adopt Industry 5.0 technologies and priorities, involving small communities, small and medium-sized companies, and individual producers.

The future orientation of Industry 5.0 is challenging for researchers. Several methods available for technology forecasting, future impacts analysis, or resilience efforts (e.g., scenario planning) can be explored. Moreover, design-oriented studies will be essential to consolidate the Industry 5.0 space. While proofs-of-concept are fundamental to Industry 4.0, illustrating how technology can be deployed, the 5.0 movement can extend past contributions with the proofs-of-impact (e.g., longitudinal studies) that may require multidisciplinary efforts.

5. Conclusion

This paper presented a bibliometric analysis and tertiary study on Industry 5.0 research. Our analysis reveals the three eras of Industry 5.0 since its initial decoupling from 4.0 in 2018. The third era shows that Industry 5.0 conquered its own space in the cross-sectoral, future-oriented, societal-driven transformation of manufacturing. Our tertiary study is a forerunner in Industry 5.0, collecting recommendations for the near future.

Several limitations must also be stated. First, we used a single database, albeit an important one. Many studies are appearing in this area, including conferences. Second, Industry 5.0 literature is intertwined with its complementary 4.0 counterpart. Although we used a systematic process and specific inclusion and exclusion criteria, our selection of the degree of Industry 5.0 focus may be subjective. Therefore, other literature reviews, publication types, or source databases may be included in future work. Finally, our recommendations also considered policy initiatives in the European area and preliminary insights from major industries collaborating with academia.

Cross-sectoral contexts are complex [45] and require effective collaborations between academia, industry, and regulators. Both Industry 4.0 (technology-driven) and Industry 5.0 (sociotechnical-driven) are expected to continue their vibrant progress, side-by-side, revolutionizing manufacturing. Aiming to improve the distinctive nature of Industry 5.0 papers, it is suggested that researchers state in their contributions (1) the sociotechnical context addressed, (2) the sustainability elements (e.g., environmental, social, or economical) addressed by technology, (3) the expected societal impacts of their study, (4) motivations for industry investment, (5) skills, and competencies [45] that need to be created to endure change, (6) regulatory implications (e.g., working with robots [42]), and (7) how the achieved sustainability improvements can be continuously measured [6] and disclosed, to ensure better futures for manufacturing agents (e.g., workers, customers) and indirect stakeholders (e.g., local populations, future generations). These aspects can be used to enrich the discussion of and increase the impact of Industry 5.0 papers.

Acknowledgements

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Appendix A. List of 32 Secondary Studies

Ref.	Application Area(s)	Examples of Challenges/Future Avenues
[1]	Manufacturing industry	Better perspective on what Industry 5.0 is and how it is perceived among the research community.
[3]	Occupational safety and health (OSH)	Development of a multi-level and multi-scale information system architecture for compliance with OSH incentive policies and their alignment with the SDGs of the Agenda 2030
[4]	(Food) supply chain management in agriculture	Strengthening of information security and confidentiality; the scalability of innovation; financial investments in agriculture; uniform standards
[5]	N/A	Open challenges of artificial intelligence: Neural network opacity; data security and data quality Open challenges for blockchain: scalability, energy consumption, transaction costs, and speed Open challenges of IoT: data security and privacy, energy consumption, interoperability
[6]	Manufacturing sector	Identification of measures and metrics able to assess hedonomics (e.g., fun, pleasure, and emotional reactions) and sustainability (e.g., carbon footprint, energy consumption, waste reduction)
[8]	Manufacturing, e.g., medical healthcare	Trajectory to Industry 6.0 with renewable energy, total machine independence, interplanetary resource gathering and manufacturing, Aerial manufacturing platforms, anatomical enhancements, quantum control.
[11]	Production Plant and Warehouse Automation	Privacy and security requirements; clarification of the role of blockchain and cyber-physical systems in Industry 5.0
[12]	sociotechnical and human segments	Development of the Industry 5.0 concept, analysis of the human role in the processes of industry digitalization, and development of the economy 4.0 and the Society 5.0 in the context of sustainable development
[13]	Engineering education	Requirement of higher education environments to reconsider their role in addition to reconsidering the role of future engineers
[14]	Trauma and Orthopedics	Sustainability, cost-effectiveness, user-friendliness, validation of systems, efficient system design, complex systems
[15]	Smart cities	Technological inefficiencies, power sources, cyber security
[16]	Manufacturing sector	Further understanding of the design challenges, e.g., ethical issues
[17]	Green housing before, during, and after Covid-19	Interdisciplinary research is required for a more comprehensive analysis of the interactions between COVID-19, the housing policies of relevant countries and cities, and their residents' behaviors and their demands for green housing.
[18]	Urban and rural farming in society 5.0	IoT connectivity
[20]	Manufacturing	Societal and technical challenges
[21]	Intelligent healthcare, cloud manufacturing, supply chain management, and manufacturing production	Critical security and privacy issues; human-robot collaboration, scalability, skilled workforce, regulatory compliance
[22]	Not specified	Call for more research in the realm of Industry 5.0
[24]	Industry in general	Worker skills and competencies, regulatory challenges, labor law, mental health
[26]	New generation of human operators, the Operator 5.0	Required changes to work organizations, skills
[40]	Manufacturing	Standardization and legalization, human adaption to Industry 5.0, implementation issues; ethical issues; skill development
[30]	Robots in hotels for improved customer experience	Determine the effect of the emotions and sentiments
[32]	Manufacturing and production industries	Proposal of a general research agenda around Industry 5.0
[33]	Ergonomics	Reorientation from a population-based approach toward an individual based science in support of Ergonomics 4.0, e.g., using AR
[34]	Manufacturing, esp. temperature in cutting processes	Design of sensors capable of providing large amounts of data that are linked to providing users with personalized products in real-time
[35]	healthcare	Technologies related to digitalization in medicine and healthcare, including virtual reality experiments, biological additive manufacturing, development of cybersecurity, and pandemic predictive big data analysis
[38]	Peatlands and agriculture	To reach an agreed consensus from stakeholders on the implementation of appropriate digital strategies to develop the peatlands, including the use of georeferencing, drones, and satellites to map the peatlands matched with physiochemical parameters, carbon sink and biodiversity
[39]	Fishery and global food supply chain	Food-water-energy nexus, circular economy, climate change and biodiversity protection, and fish welfare that includes a supply chain for safe, nutritious feed and disease mitigation
[41]	Maritime industry, autonomous shipping	Required skills and competencies; implementation issues
[42]	Cross-industry perspective	Legal and regulatory issues regarding robots, psychological issues
[43]	Discrete Event Simulation (DES)	Reality integration, hybrid simulation, interoperability of production machines, artificial intelligence and its narratives, neutrality

Ref.	Application Area(s)	Examples of Challenges/Future Avenues
[44]	Taxonomy of Blockchain Applications in Industry 5.0.	Development challenges, security, and safety challenges
[45]	manufacturing	Social heterogeneity in terms of values and acceptance; Measurement of environmental and social value generation; Integration from customers across entire value chains to SMEs; Interdisciplinarity of research disciplines and system complexity; Ecosystem-oriented innovation policy with agile, outcome orientation; Productivity is required, while large investments are needed

An extended table version is available online: https://data.mendeley.com/datasets/nd48nwsnjn/1

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