

Human-Centricity in Industry 5.0: A Bibliometric Mapping Study

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Abstract. *The transition to Industry 5.0 has intensified scientific research interest in one of the three pillars of this new paradigm, such as the human-centric dimension, which highlights the way in which orientation towards humans redefines the relationship between workers and advanced technologies, underlining the complementarity among humans’ way of thinking and systems like artificial intelligence, digital twin, collaborative robots, or cyber-physical systems. The methodological approach used in this study is a bibliometric analysis. The database used is Web of Science Core Collection. The exported dataset consists of scientific articles that were selected based on a query and published between 2022 and 2026. Then, the analysis of the exported and filtered dataset was conducted in the VOSviewer software to generate the co-occurrence of keywords, co-citations for sources and authors, and bibliographic coupling maps. The overview of the analyzed corpus and the results reveal different perspectives of human-centricity within Industry 5.0, authors, and notable publications, as well as thematic clusters relevant to the topic of this research. This paper contributes to the academic literature by identifying and analyzing different types of human-centricity and offers a conceptual understanding that can support future theoretical and practical developments.*

Keywords: human-centric approach, Industry 5.0, bibliometric analysis, advanced technologies, artificial intelligence, human-machine collaboration, sustainability.

Introduction

Industry 5.0 comes with the idea that as technologies continue to advance and are integrated into the industrial processes, the role of people should be kept and even strengthened. In other words, technology makes sense only when it supports people, and this orientation to the human-centric approach changes the way we currently understand work and the role of organizations. So, from the Industry 5.0 point of view, instead of seeing automation as a way of replacing people, the collaboration between humans and machines is being encouraged, so each side leverages its strengths. In this case, employees’ well-being, autonomy, and professional development are essential conditions of working for long-term performance and sustainability.

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The main objective of this study is to conduct a bibliometric analysis of human-centered research regarding Industry 5.0, using data from the Web of Science (WoS) Core Collection, and visualizations generated with VOSviewer. In this way, it is possible to identify the leading authors, articles, main thematic clusters, and future research directions. This analysis provides a perspective on the concept of human-centricity, which can be understood through different types: functional-technical, normative-ethical, and organizational-relational. The research questions of this study are:

RQ1: What are the approaches of human-centricity identified in the corpus?

RQ2: Which thematic clusters and main research directions can be identified through analysis?

RQ3: What themes that are underexplored can be identified from the analysis?

This article is structured as follows: it starts with a theoretical part exploring Industry 5.0 and the types of human-centricity that are identified within analyzed studies. Then it continues with the methodological approach used to select and analyze the dataset, as well as the results and discussions based on findings. In the end, there are conclusions and some recommendations for future research directions on this topic.

Literature review

Industry 5.0: concepts and principal fundamentals

Industry 5.0 came as a response to the limitations of Industry 4.0 (a model that is oriented more towards automation, efficiency, and performance through advanced digital technologies) and introduces a complementary vision for the industrial development in which humans are being brought back to the main stage in the production system. Moreover, the new model focuses on sustainability, resilience, and social responsibility, using technology as a supporting tool for humans, not as a substitute (Pathak et al., 2025; Yanytska, 2025).

According to the approaches discussed in the specialized literature, Industry 5.0 is described as an evolved model of production that wants to strengthen the collaboration between humans and smart systems (Adel, 2022). What does this collaboration mean? It means the combination of each leverage, like the efficiency, accuracy, and advanced analytical capabilities of automated and intelligent technologies, with the intuition, talent, and cognitive skills of human factors. This synergy enables the configuration of flexible manufacturing processes that are oriented toward the individual's needs. This visionary model can offer significant benefits for organizations and society. Some examples would be enhancing the market positions of enterprises, attracting and developing talent, and improving working conditions, with the help of technologies that support the improvement of resource allocation and decreasing negative effects on the environment. Besides these, the potential of Industry 5.0 is also viewed through the humanoid robots and systems that support decision-making, also highlighted by the important relationship between people and machines (Adel, 2022; Pathak et al., 2025).

Human-centricity in Industry 5.0: types and associated technologies

The concept of Industry 5.0 is supported by a set of ascending technologies that extend the competencies of existing industrial systems and are integrated into a wider perspective centered on sustainability, resilience, and social impact (Tallat et al., 2024).

In the literature on Industry 5.0, the concept of human-centricity can be understood through different perspectives: functional-technical, which is focused on adapting technology and workplaces to the needs and capabilities of employees; normative-ethical, which emphasizes rights,

justice, and social responsibility; and the organizational-relational perspective, focused on the active involvement of workers in work decisions and processes.

The functional human-centricity perspective accentuates the creation of workplaces and technological systems in such a way that they support both process efficiency and employee health and well-being. The concept of human-centered design, in combination with user experience (UX) principles, allows tasks and interaction with technology to be adapted to the cognitive, perceptual, and physical needs and abilities of workers. The wearable technologies, like smart watches, motion capture devices, or posture monitoring systems, as well as augmented and virtual reality solutions, offer real-time data on employee posture and activity. They facilitate the simulation and optimization of the way they work and prevent overload or accidents. Software tools like “JACK”, “HumanCAD”, or “Siemens Tecnomatix” allow the assessment of biomechanical risks and ergonomic work planning. They even consider the diversity of employees, including different levels of experience or disabilities. In addition, integrating collaborative robots and AR systems into work processes can reduce monotony, support personalized training, and increase the satisfaction of employees. Real-time responses and analysis of physical and behavioral data are facilitating the continuous adjustment of workplaces so that there is a balance between automated and human tasks. This helps with reducing the risks of overload and creating a safer, more efficient, and truly human-centered work environment (Trstenjak et al., 2024).

The following interesting practical examples from a research paper by Grosse et al. (2023) also highlight the ergonomic and technical functional focus of the human-centric approach presented in this paper: Ulmer et al. (2023) present augmented manual workstations with augmented reality (AR), where equipment and information flows are customized according to the skills of each operator. De Lombaert et al. (2023) analyze models that pick orders in warehouses and integrate ergonomic factors and individual worker behaviors to increase employee productivity and well-being. De Assis Dornelles et al. (2023) highlight the impact that cobots have on workers’ skills, where more advanced interactions bring about both upskilling and deskilling, depending on the type of relationship (coexistence, synchronization, cooperation, or collaboration). In order to show how important it is to incorporate the human perspective into the system design, these studies are using ergonomic and cognitive metrics, accounting for workforce diversity, and adapting technologies to individual skills (Grosse et al., 2023).

Despite all the above, sometimes, the increased collaboration between humans and smart systems raises ethical and organizational questions about how these technologies influence the workforce and labor relations (Longo et al., 2020). Taking this into account, based on recent literature and regulatory sources (Re Cecconi et al., 2025), AI and collaborative robots must be designed in compliance with the principles of transparency, accountability, privacy, security, and respect for human rights, in order to be accepted and effective (Longo et al., 2020; Tallat et al., 2024; Yanytska, 2025). In this case, AI Act, ISO, IEEE, ALTAI, or GDPR provide clear guidelines for the design of ethical AI systems. These include audit, explainability, and human control over automated decisions, to prevent abusive or unfair use of the technology. Also, the standards for high-risk systems outline the need for AI to protect users' safety and autonomy, prevent harm, and ensure the fair distribution of technological benefits (Re Cecconi et al., 2025). In parallel, Pizoń et al. (2022) show that placing humans at the center of the industrial ecosystem is a complex and practical process, not just a theory. Cobots and personalized AI must learn to adapt to the individual differences of employees, their work style, and skills, in order to create an effective and motivating collaboration with them. In addition, the implementation of intelligent technologies changes the

dynamics of teams, requires continuous training, skills development, and redefining roles in organizations. So human resources must ensure that assigning tasks to robots does not reduce human autonomy and responsibility, but complements it (Tallat et al., 2024; Yanytska, 2025). The challenges of data security, privacy, and integrity are thus interconnected with ethical responsibility and the adoption of human-centered design (Pizoń et al., 2022). A relevant example of this cooperation is collaborative robots or cobots (Adel, 2022), which significantly change the structure of work activities. Cobots undertake repetitive or physically demanding tasks, while human workers focus on activities that require human attributes (Adel, 2022; Tallat et al., 2024). However, studies also point out the risks associated with this cooperation, such as reduced social interactions, hesitation to robot-assisted learning, and the perception of competition between humans and machines (Longo et al., 2020). Big-data analysis and the use of cloud and edge computing infrastructures increase the functioning of Industry 5.0 digital ecosystems, allowing the quick processing of information and dynamic adaptation of industrial processes (Adel, 2022; Tallat et al., 2024). On top of that, the expansion of data collection and its use generates issues related to privacy, security, and surveillance, which directly influence the level of acceptance of technology by employees (Longo et al., 2020). These aspects outline the need for governance mechanisms that secure a balance between efficiency and the protection of human core values (Yanytska, 2025). Technologies such as blockchain and 6G networks are considered necessary for warranting security, traceability, and reliability of communications in advanced industrial environments (Tallat et al., 2024). Despite this, their integration process into organizations is often limited by the lack of common standards and high implementation costs, which can lead to inefficient solutions (Adel, 2022; Tallat et al., 2024). In terms of ethical and organizational perspectives, these difficulties can accentuate inequalities between companies, with those that lag technologically (Longo et al., 2020). To sum up, a normative and ethical human-centricity approach is not limited only to values; it needs concrete governance mechanisms, accountability frameworks, and design principles in order to protect the employees' rights and the cooperation with smart technologies (Adel, 2022; Pizoń et al., 2022).

When it comes to the organizational-relational approach, in a recent study, Mabrouk (2026) proposed an evaluation system based on holistic performance within Industry 5.0 that embraces advanced technologies with continuous employee development and organizational values. This system is based on constant feedback and real-time coaching (through regular discussions, peer reviews, and AI platforms), holistic assessment of cognitive, socio-emotional, and digital skills, monitoring workers' health and involvement, reducing bias in the evaluation of performance, and setting flexible goals for organizational strategy and Industry 5.0 principles. So, with the help of this method, the human factor is seen as an involved participant in the evolution of the production and logistics system, not only as a resource (Padovano, 2023; Mabrouk, 2026).

Methodology

The methodological approach used in this study is a bibliometric analysis, which is a quantitative method that can help us understand the scientific literature through numbers, like how many articles have been published, who cites whom, and what topics, documents, or authors are popular (Passas, 2024).

The data used for this study were extracted from the Web of Science Core Collection. The search in the Topic (TS) field includes title, abstract, and author keywords and guarantees that the selected articles are relevant to the targeted concepts. The search query included two conceptual

blocks that were connected by the Boolean operator AND, so that each selected article addresses all relevant dimensions simultaneously: the concept of Industry 5.0, the human-centric part, and the collaboration between humans and machines. Within each block, the OR operator was used to include synonyms or terminological variations, to expand coverage, and identify as many relevant articles as possible. The final query had the following structure: ("Industry 5.0" OR "Industry 5 0") AND ("human centric*" OR "human-centered" OR "human-machine collaboration"). In the search query, the search used the truncation operator "*" to include all possible variations of a term. This operator allows the database to retrieve forms of the same concept. This method is called truncation. It guarantees complete coverage and reduces the fragmentation of terms during the co-occurrence analysis stage (Bezot, n.d.).

After obtaining 1121 results, several filters were applied to increase the relevance and quality of the dataset. Firstly, only original articles (*Articles*) and scientific reviews (*Review Articles*) were selected as they represent valid research and theoretical syntheses of the field. Proceedings, Early Access, or Editorial Material works, which are either not fully standardized or do not represent original contributions to the literature, were excluded. Secondly, a time window was set for the most recent years (2022-2026), motivated by the concept's recent and growing nature and interest, even though this paradigm discourse began earlier, around 2020-2021. Figure 1 shows the number of publications and the number of citations over the selected time span. The highest point in both publications and citations from this dataset is in 2025 (approximately 106 publications and 2869 citations). Even though citation counts for 2026 are partial, being still at the beginning, the numbers, 7 and 244, respectively, suggest a promising debut, with increasing potential as the year advances and indexing is still in progress.

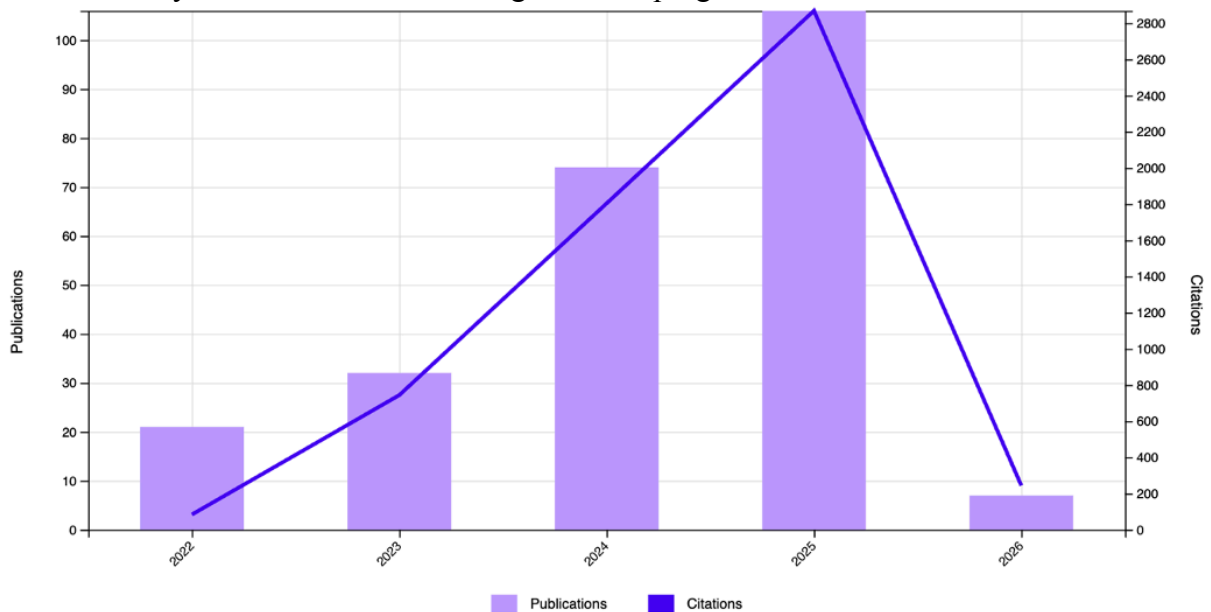


Figure 1. The evolution of publications and citations between 2022 and 2026

Source: Authors' own research.

In order to guarantee consistency and access to most of the cited international literature in the bibliometric analysis, the language was limited to English. The next step was the selection of relevant categories (Web of Science Categories) like "Engineering Industrial", "Robotics", "Ergonomics", and "Automation Control Systems" to avoid including irrelevant articles for this topic.

The query returned a set of 240 articles, representing the relevant literature for this analysis. The selected articles were then exported with the “Full Record and cited references” option and prepared for bibliometric analysis. Some fields, like “Author Keywords” and “Keywords Plus” from the raw form of the exported file, contained variations of the same term (e.g., spacing differences, punctuation marks, or separators such as “;”), which resulted in entries with a value of 0 (zero) appearing in the co-occurrence analysis performed in VOSviewer. So, to make sure the bibliometric analysis is accurate, the dataset was preprocessed. Generally, this phenomenon is common in exported bibliometric data, and if it is not corrected, it can affect the structure of the keyword network.

Figure 2 presents the PRISMA 2020 flowchart, representing the methodological process of this study.

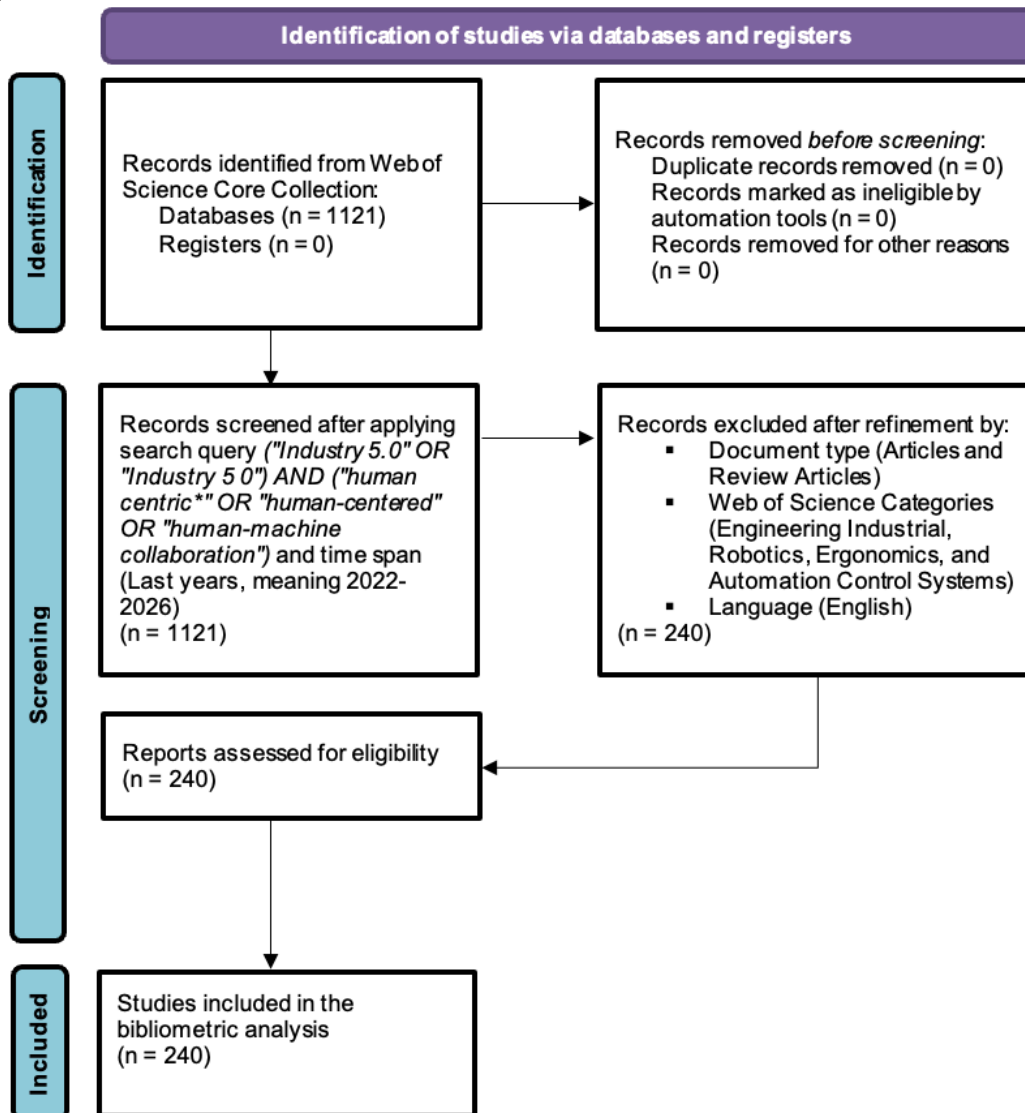


Figure 2. Research methodological framework

Source: Authors' own research and Page MJ, et al. BMJ 2021; 372:n71. doi: 10.1136/bmj.n71.

Table 1 contains the 10 most relevant papers by their citation number that have significantly contributed to the topic of the human-centric approach of Industry 5.0. This is based on the citation report generated in Web of Science.

Table 1. The most cited articles on the human-centric approach of Industry 5.0 (2022-2026)

No.	DOI	Year	Journal	Citations				
				2022	2023	2024	2025	2026
1.	https://doi.org/10.1016/j.jmsy.2022.09.017	2022	JMS	11	112	253	245	18
2.	https://doi.org/10.1080/00207543.2022.2118892	2023	IJPR	4	88	130	184	14
3.	https://doi.org/10.1016/j.jmsy.2022.02.001	2022	JMS	32	103	147	116	12
4.	https://doi.org/10.1016/j.jmsy.2022.07.010	2022	JMS	10	74	111	116	11
5.	https://doi.org/10.1016/j.rcim.2023.102626	2024	RCIM	0	7	92	116	8
6.	https://doi.org/10.1016/j.jmsy.2022.04.007	2022	JMS	8	46	56	51	4
7.	https://doi.org/10.1080/00207543.2022.2138611	2023	IJPR	1	21	59	77	1
8.	https://doi.org/10.1016/j.jmsy.2023.01.004	2023	JMS	0	18	57	70	7
9.	https://doi.org/10.1080/21681015.2023.2216701	2023	JIPE	0	13	55	68	2
10.	https://doi.org/10.1016/j.jmsy.2022.11.004	2022	JMS	0	34	47	44	2

Source: Web of Science citation report.

Note. Journal of Manufacturing Systems (JMS); International Journal of Production Research (IJPR); Robotics and Computer-Integrated Manufacturing (RCIM); Journal of Industrial and Production Engineering (JIPE).

Then, the exported and preprocessed *.txt* file was imported into the VOSviewer software, and the “Create a map based on bibliographic data” option was selected to generate keyword co-occurrence, co-authorship, and co-citation maps. Finally, the dataset was imported and processed using the “Read data from bibliographic database files” function, which facilitates the construction of the maps.

Results and discussions

The H-Index for the dataset of 240 articles included in this study is 35 and indicates a high level of influence and visibility of the literature in this analyzed topic.

The analysis of co-occurrence keywords

Figure 3 presents the semantic structure of Industry 5.0, based on the co-occurrence of keywords extracted from literature. This analysis was performed on a set of 50 out of 312 terms that met the threshold, with at least 2 occurrences. The choice of this threshold shows a balance between covering relevant terms and reducing informational noise. The choice of a single threshold would have generated numerous low-significance clusters, whereas a higher threshold (e.g., 3 or 4) would have excluded emerging or relevant terms and reduced the network's informational value. The preliminary checks that have been conducted with alternative thresholds showed that the main clusters identified remain consistent, confirming the robustness of the network's structure to moderate variations. The resulting terms were distributed across six thematic and colored clusters, connected by 304 links, with a total link strength of 443, indicating a dense and coherent network.

The *yellow* cluster revolves around the central concept “Industry 5.0,” and includes terms such as “human-centric design,” “ergonomics,” “manufacturing,” and “logistics,” illustrating the functional-technical perspective of human-centricity, and focusing on the adaptation of systems to the cognitive and physical capacities of operators. The *red* cluster integrates “Industry 4.0” and

digital technologies, such as “explainable artificial intelligence,” “implementation,” “digital twin,” and “supply chain resilience,” revealing the normative-ethical perspective. The *green* cluster connects terms like “innovation,” “sustainability,” and “resilience” with sustainable organizational strategies and human-centered innovation, while the *blue* cluster presents the integration of advanced technologies and the interest in training and simulation, through terms like “simulation,” “virtual reality,” and “large language model”. Lastly, the *purple* cluster is relevant to the relational-organizational type of human-centricity and focuses on human-machine collaboration and operator-centered design, as reflected in terms like “human-robot collaboration,” “mental workload,” and “human-centric manufacturing”.

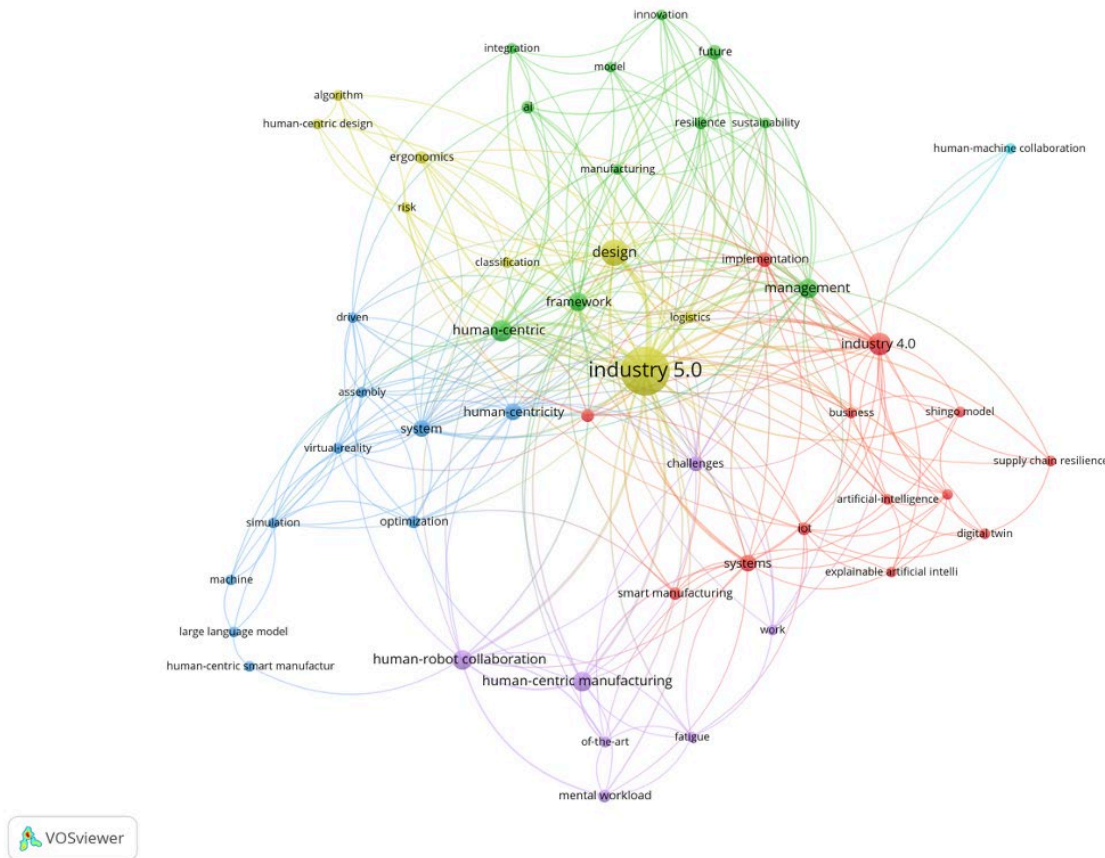


Figure 3. Keywords co-occurrence clusters

Source: Visualization generated with VOSviewer.

Figure 4 shows the time map generated with the overlay function of VOSviewer, in which the node colors indicate the time of appearance of terms in our dataset.

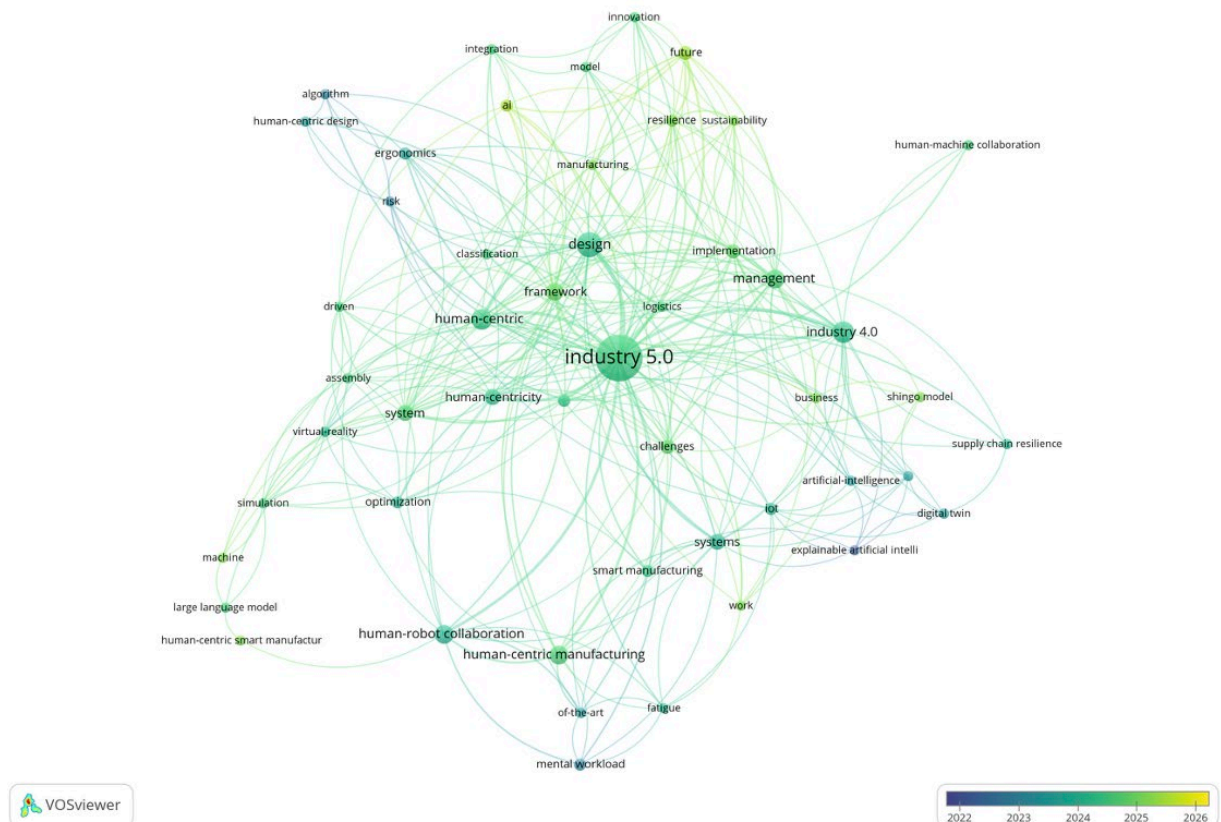


Figure 4. Time map analysis

Source: Visualization generated with VOSviewer.

The analysis of the most-cited articles in the dataset used

Table 2 consists of a qualitative analysis of the main relevant articles from the corpus in order to understand how the recent literature on Industry 5.0 and the human-centered approach addresses the human role, power, and risks associated with emerging technologies. In this context, the present study identified the type of human-centered approach present in each paper from the corpus, classifying them into:

- Functional-technical – focused on performance, productivity, and efficiency;
- Normative-ethical – focused on values, ethics, safety, and workers' rights;
- Organizational-relational – focused on the social role, collaboration, organization, and impact on workers.

Table 2. Overview of the most cited articles on the human-centric approach of Industry 5.0

No.	Article title and authors	Overview
1.	Industry 5.0: Prospect and retrospect - Leng et al., (2022)	The article presents Industry 5.0 as an industrial evolution that places human well-being, sustainability and resilience at the center of technical and application systems. The risks identified include the diversity of technologies, interdisciplinary challenges, differences in values between countries and issues of security and human-robot collaboration. The approach is functional-technical, complemented by a normative approach, oriented towards a symbiotic and sustainable industry.

No.	Article title and authors	Overview
2.	The Industry 5.0 framework: viability - based integration of the resilience, sustainability, and human-centricity perspectives - Ivanov, (2023)	Industry 5.0 is presented as a technological and organizational framework that integrates resilience, sustainability, and human-centricity into operations and supply chains. The risks identified lie in the complexity of aligning these objectives at societal, network, and factory levels. The approach is functional-technical, complemented by a normative dimension that is oriented toward human well-being and societal value.
3.	Outlook on human-centric manufacturing towards Industry 5.0 - Lu et al., (2022)	The article proposes a normative vision of human-centric manufacturing and argues that the future factories must respond to the full spectrum of human needs, from safety and health to belonging, esteem and self-actualization. Moreover, the human-machine collaboration is reimagined as a process of 5C in which technology becomes an empathetic partner, not a tool of control. The risks identified relate to the lack of a mature conceptual framework and the difficulty of transforming these ideals into real industrial practices. Human-centricity is predominantly functional-technical with normative-ethical elements.
4.	Industry 5.0 and Society 5.0 - Comparison, complementation and co-evolution - Huang et al., (2022)	The article presents a normative vision of Industry 5.0 and Society 5.0, in which people become the center of industrial and social transformation, and technology is a way to support well-being, personalization and inclusion. The authors compare the two concepts and show that both pursue a society and industry oriented towards the needs of the individual, supported by advanced technologies such as digital twins, AI and human-cyber-physical systems. The approach is predominantly normative-ethical, with organizational elements, emphasizing values, well-being and social impact, rather than operational efficiency.
5.	Human Digital Twin in the context of Industry 5.0 - Wang et al., (2024)	Introduces the concept of Human Digital Twin (HDT) as a key technology for achieving human-centricity in Industry 5.0, by integrating human needs and characteristics into the design of intelligent systems. The approach is predominantly functional-technical, with normative-ethical elements, oriented towards well-being and personal development and supported by technological elements. The risks discussed are mainly related to technological maturity and the lack of standardized frameworks, transparency, complete modeling and data protection.
6.	Evaluating quality in human-robot interaction: A systematic search and classification of performance and human-centered factors, measures and metrics towards an industry 5.0 - Coronado et al., (2022)	The paper analyzes human-centric factors and metrics used to assess the quality of human-robot interaction in the context of Industry 5.0. In addition, it emphasizes the need to integrate well-being, trust, safety and mental load into performance evaluation. The authors show that Human-Robot Interaction (HRI) must go beyond simple task performance and become truly human-centric. They identify emerging directions such as non-invasive monitoring, system transparency and data protection. The approach is mainly normative-ethical, with a touch of functional-technical component, but subordinated to human well-being.
7.	Human-centric artificial intelligence architecture for industry 5.0 applications - Rožanec et al., (2023)	The article proposes an AI architecture for Industry 5.0 built on values like safety, trust and human-centricity and integrates modules such as reality simulation, forecasting, XAI, active learning and intention recognition. The risks are related to transparency, explainability, cybersecurity and standardization. Overall, the approach is normative-ethical, with a technical-functional component for practical implementation.

No.	Article title and authors	Overview
8.	Flexible job shop scheduling problem under Industry 5.0: A survey on human reintegration, environmental consideration and resilience improvement - Destouet et al., (2023)	The research analyzes “Flexible Job Shop Scheduling Problem” (FJSSP) and integrates human, environmental and resilience factors into the planning models. The challenges come from combining economic objectives with worker well-being and energy sustainability. The approach is functional-technical but is guided by a normative-ethical vision specific to Industry 5.0.
9.	Behind the definition of Industry 5.0: a systematic review of technologies, principles, components, and values - Ghobakhloo et al., (2023)	The article provides a systematic analysis of Industry 5.0 and presents it as a paradigm driven by socio-ecological values and clearly differentiating it from Industry 4.0. The authors propose a conceptual archetype based on the cognitive technologies and the involvement of all actors in the governance of digital transformation. The approach is predominantly normative-ethical, but also includes a functional component, as advanced technologies are integrated to support responsible and efficient industrial development.
10.	Human centric platforms for personalized value creation in metaverse - Mourtzis et al. (2022)	The article analyzes how the Metaverse can support a human-centered society and industry, through digital platforms that enable personalization and immersive interactions. The risks identified are related to digital identity, security, privacy, lack of regulations, psychological impact, and the difficulty of standardizations and interoperability. The approach is functional-technical, through the analysis of software architectures and XR technologies, but guided by a normative-human vision of creating a safe and user centered digital ecosystem,

Source: Authors’ own research.

The analysis of the articles included in the corpus selected for this study highlights a contradiction between the theoretical discourse of Industry 5.0 and the dominant directions identified in the analyzed literature. Even though the investigated publications frequently promote the idea of a human-centered industry, the bibliometric results show that it is oriented towards technologies, systems optimization, and operational efficiency. This aspect suggests that the human-centric component is associated mainly with improving the human-machine collaboration, and less with practical organizational or social transformation. At the same time, the identification of the type of approach of articles indicates the predominance of functional-technical perspectives within the selected publications. Most studies treat the human factor as an integrated element in the smart production systems, but less often as an active participant. While many studies promote the idea or concepts like sustainability, resilience, and employee well-being, these often remain at the theoretical level and are less integrated into concrete industrial applications. The results suggest that the literature in the analyzed corpus still maintains an orientation close to the Industry 4.0 paradigm, focused on efficiency and digitalization, even if it uses a more human-centered discourse.

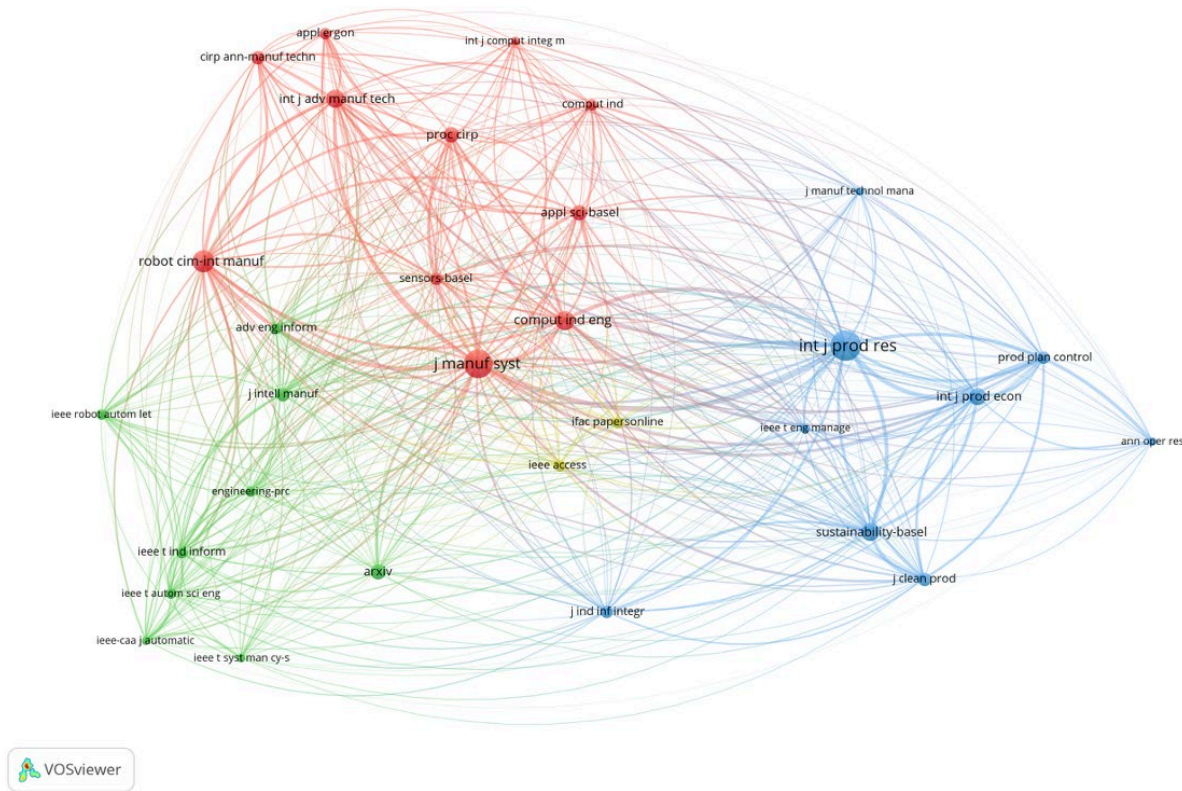


Figure 5. Co-citation for sources

Source: Visualization generated with VOSviewer.

Figure 5 presents the co-citation of sources and provides a clear picture of the contributions that have shaped recent academic research on the topic of the present study. The JMS, the IJPR, and RCIM stand out for the frequency and impact of their published research papers. In addition, a co-citation analysis for authors was conducted, as shown in Figure 6, with a minimum of 20 citations per author, on a set of 3.221 authors, of which only 7 met the criterion, indicating a significant concentration of citations around a small group of researchers.

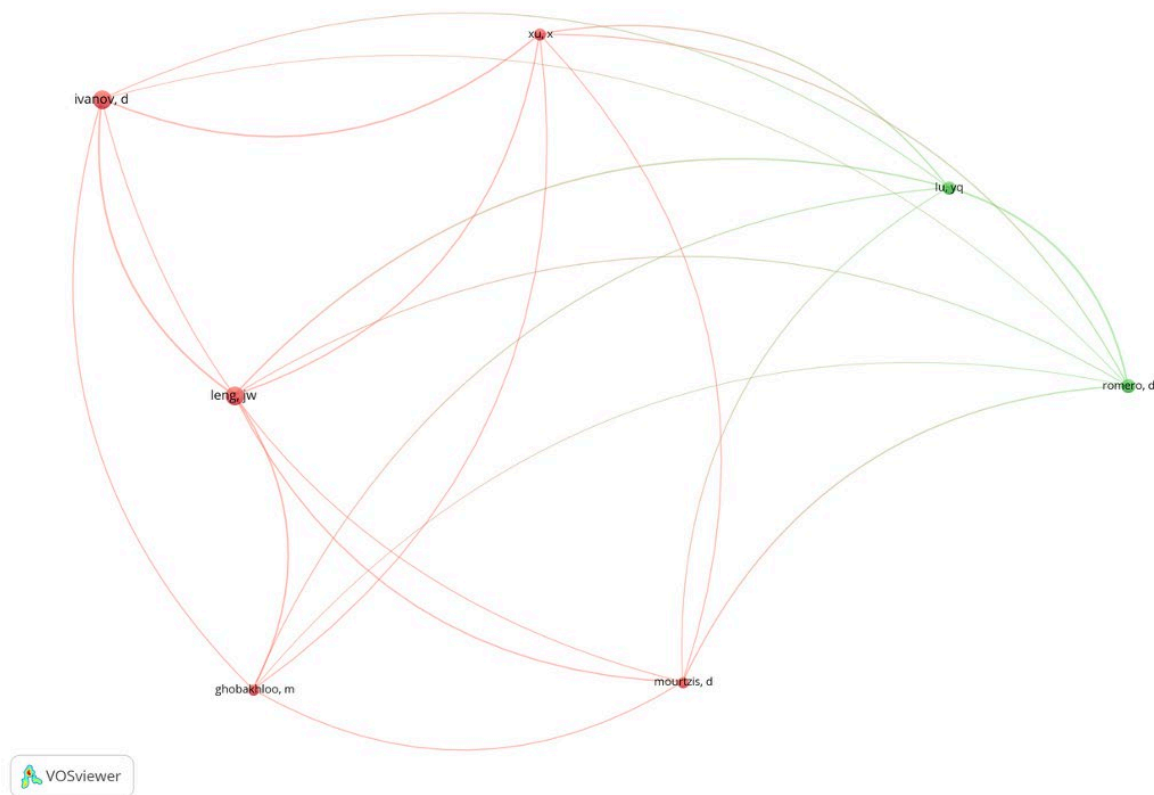


Figure 6. Co-citation for authors

Source: Visualization generated with VOSviewer.

Figure 7 presents a bibliographic coupling of documents that was performed at the author level, with labeling “name (year)” that outlines the evolution of collaborations over time. Out of the 50 documents, only 27 meet the criteria (minimum 5 citations per article), setting up a coherent network of papers that share common references.

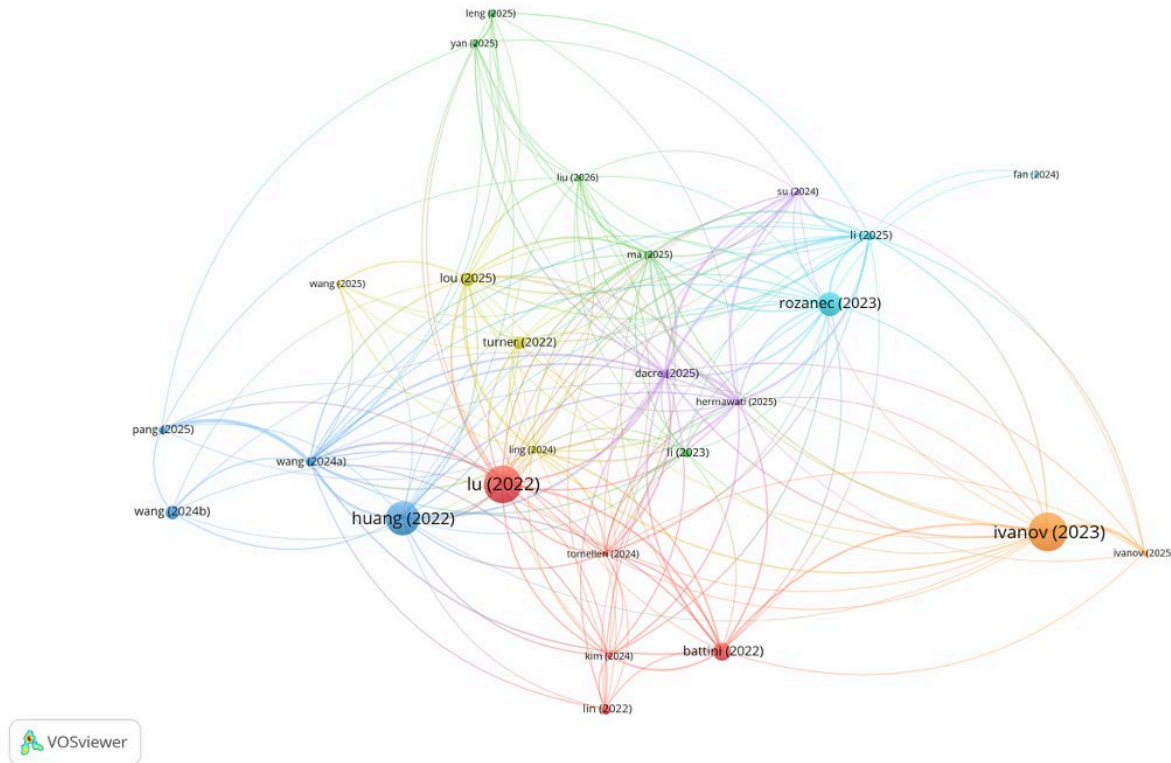


Figure 7. Bibliographic coupling for documents

Source: Visualization generated with VOSviewer.

Conclusion

The present study offers an integrated perspective of the human-centered approach. In the first part, the study presented the conceptual framework of the human-centric paradigm, the distinctive pillar of Industry 5.0. The association between the human dimension and smart technologies was analyzed as a process of co-evolution, in which the smart systems do not replace but amplify human capabilities, and support human inventiveness, well-being, and decision-making in some contexts. This theoretical introduction provided the necessary direction and understanding for the interpretation and analysis of the bibliometric results. The second part consists of results in discussions based on a bibliometric analysis of a dataset of 240 articles.

The co-occurrence analysis of the keywords and the overview of the most cited articles from our dataset show that human-centricity in Industry 5.0 is defined by a combination of approaches. The predominant perspective is the functional-technical one and focuses on the integration of advanced technologies into resilient, sustainable, and adaptable systems. This perspective is complemented by a normative-ethical component that introduces values such as workers' well-being, social responsibility, sustainability, and human-machine collaboration, without transforming the Industry 5.0 model into a purely organizational or relational one. The findings suggest that dominant literature develops a narrative of the harmonious collaborations between humans and machines, and the critical or explicitly work-centered dimensions remain less present. This absence indicates a gap, and future research can deepen the social, relational, and ethical implications of Industry 5.0, beyond the technical architectures and functional models.

Overall, the results not only map the current state of research in the human-centered dimension within Industry 5.0 and its collaborative relationship with enabling technologies but also

provide a basis for guiding future investigations, guaranteeing both continuities and development opportunities in a field that is in continuous transformation.

Limitations and future research directions

Because of the bibliometric approach, the paper is subject to certain limitations. The analysis was based on articles from Web of Science Core Collection, which may exclude relevant contributions published in other databases. In addition, the filtering process that was applied may omit relevant works that do not use standardized terminology or are indexed in related areas. The dominant literature tends to reduce the concept of human-centricity to ergonomics and productivity optimization, without sufficiently addressing workers' real well-being, autonomy, rights, or agency. Their voices and unions are almost absent. While emerging economies and other contexts are poorly represented, the Global North/EU perspective predominates. So future research directions may integrate qualitative methods, case studies, and professional interviews to explore more deeply the social, political, and ethical aspects, as well as different perspectives of industrial actors and workers, to complement the picture dominated by the human-technology narrative.

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References

- Adel, A. (2022). Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas. *Journal of Cloud Computing* 2022 11:1, 11(1), 40-. <https://doi.org/10.1186/S13677-022-00314-5>
- Bezetz, A. (n.d.). *LibGuides: The Research Process: Truncation & Wildcard Symbols*. Retrieved 13 January 2026, from <https://resources.nu.edu/researchprocess/truncation>
- Grosse, E. H., Sgarbossa, F., Berlin, C., & Neumann, W. P. (2023). Human-centric production and logistics system design and management: transitioning from Industry 4.0 to Industry 5.0. *International Journal of Production Research*, 61(22), 7749–7759. <https://doi.org/10.1080/00207543.2023.2246783>; JOURNAL:JOURNAL:TPRS20;WGROU:STRING:PUBLICATION
- Longo, F., Padovano, A., & Umbrello, S. (2020). Value-Oriented and Ethical Technology Engineering in Industry 5.0: A Human-Centric Perspective for the Design of the Factory of the Future. *Applied Sciences* 2020, Vol. 10, Page 4182, 10(12), 4182. <https://doi.org/10.3390/APP10124182>
- Mabrouk, A. (2026). Beyond the Numbers: Reimagining Human Performance Evaluation in the Age of Industry 5.0. *Solo International Collaboration and Publication of Social Sciences and Humanities*, 4(01), 1–12. <https://doi.org/10.61455/SICOPUS.V4I01.372>
- Padovano, A., Cardamone, M., Woschank, M., & Pacher, C. (2023). Exploring Human-Centricity in Industry 5.0: Empirical Insights from a Social Media Discourse. *Procedia Computer Science*, 232, 1859-1868. <https://doi.org/10.1016/j.procs.2024.02.008>

- Passas, I. (2024). Bibliometric Analysis: The Main Steps. *Encyclopedia 2024, Vol. 4, Pages 1014-1025*, 4(2), 1014–1025. <https://doi.org/10.3390/ENCYCLOPEDIA4020065>
- Pathak, R., Singh, H., & Singh, M. (2025). INDUSTRY 5.0 : A HUMAN-CENTERED APPROACH FOR OPTIMIZING DIGITAL TRANSFORMATION. *The Kashi Journal of Commerce Issue XX, 1*, 1–15. CENTERED_APPROACH_FOR_OPTIMIZING_DIGITAL_TRANSFORMATION
- Pizoń, J., Witczak, M., Gola, A., & Świć, A. (2022). Challenges of Human-Centered Manufacturing in the Aspect of Industry 5.0 Assumptions. *IFAC-PapersOnLine*, 56(2), 156-161. <https://doi.org/10.1016/j.ifacol.2023.10.1562>
- Re Cecconi, F., Khodabakhshian, A., Rampini, L. (2025). Industry 5.0 in Construction: Towards a More Human-Centric and Ethical AI. In: *Building Tomorrow: Unleashing the Potential of Artificial Intelligence in Construction*. SpringerBriefs in Applied Sciences and Technology(). Springer, Cham. https://doi.org/10.1007/978-3-031-77197-2_6
- Tallat, R., Hawbani, A., Wang, X., Al-Dubai, A., Zhao, L., Liu, Z., Min, G., Zomaya, A. Y., & Hamood Alsamhi, S. (2024). Navigating Industry 5.0: A Survey of Key Enabling Technologies, Trends, Challenges, and Opportunities. *IEEE Communications Surveys and Tutorials*, 26(2), 1080–1126. <https://doi.org/10.1109/COMST.2023.3329472>
- Trstenjak, M., Benešova, A., Opetuk, T., & Cajner, H. (2024). Human Factors and Ergonomics in Industry 5.0—A Systematic Literature Review. *Applied Sciences*, 15(4), 2123. <https://doi.org/10.3390/app15042123>
- Yanytska, L. (2025). The rise of human-centric manufacturing in the industry 5.0 era. *The International Journal of Advanced Manufacturing Technology* 2025 139:9, 139(9), 5067–5077. <https://doi.org/10.1007/S00170-025-16192-5>