Exploring Human Centricity in Industry 5.0: A Systematic Review

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Abstract

This study examines the concept of "human centricity" in the context of Industry 5.0 through a systematic literature review. It explores the evolution of human-centricity in industry, spanning from the pre-Industry 5.0 era to its adoption and advancements in state-of-the-art initiatives. This research uses the systematic literature review (SLR) methodology, following PRISMA guidelines. Scopus and Web of Science databases are utilized for comprehensive research, and VOSviewer is employed for keyword mapping analysis. The findings of the study shed light on the progression of enabling technologies associated with human-centricity in the industrial context. Through bibliographic analysis and literature synthesis, the research provides insights into human-centricity within the frameworks of Industry 4.0, Society 5.0, and Industry 5.0, offering a comprehensive overview of current practices, state-of-the-art initiatives, and enabling technologies. Ultimately, this systematic review significantly contributes to the understanding of human-centricity in the context of Industry 5.0, providing valuable insights into its evolution, existing practices, initiatives, enabling technologies, and potential areas for future research.

Keywords
Industry 5.0, human-centric*, Industry 4.0, Society 5.0

1. Introduction
Industrial revolutions primarily aim to transform the technological landscape of a particular era. Throughout history, it has been widely acknowledged that technological advancements play a pivotal role in driving value creation, exchange, and distribution. *(Xu et al. 2021b)*. Studies have shown that the general well-being of workers has greatly improved over the years due to the gradual annihilation of labor-intensive tasks, production improvements, and time savings with the progression of each revolution. (Krekel et al. 2019) In light of the impact of technological advancements on value creation, exchange, and distribution, the emerging concept of 'human centricity' has become a pivotal focus in the industry. It is crucial for technologies to be intentionally designed to align with future social values, as emphasized by Xu et al. (2021).

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The primary aim of promoting a shift towards a human-centered industry paradigm is to improve the overall well-being of individuals. This includes acknowledging and appreciating the role, needs, job, talents, and rights of people within the industry. Coronado et al. (2022) define Industry Human centricity as prioritizing human well-being and embracing a human-centered perspective across all aspects of the industry.

In recent times, there has been a strong inclination towards a future driven by digitization, interconnection, automation, cloud computing, and big data, which aimed primarily at economic gains in the context of Industry 4.0 (EIT Digital Professional School 2022). Industry 4.0, with its integration of disruptive technologies and intelligent analytics like IoT, CPS, big data, and artificial intelligence (AI), has not only transformed the manufacturing industry but has also had a significant impact on all sectors of the economy (Jafari et al. 2022).

As industry 4.0's main objective is to increase process effectiveness, it unintentionally ignores the human cost associated with process optimization (Nahavandi 2019). Despite various initiatives, such as Operator 4.0 and the concept of the 'factory of the future,' aimed at reconciling productivity with the role of humans (Romero, Stahre, & Taisch 2020), there is a growing recognition for the need of a new design and engineering philosophy to achieve human-centric and cyber-physical production systems.

In recent times, there has been a notable resurgence in the focus on incorporating human labor into industrial production processes while leveraging the advantages of machines. This has sparked considerable interest among industry and academia in exploring the potential of integrating human and robotic resources in collaborative production environments. (Kemény, Z. et al. 2021)

The European Union has introduced the subsequent phase of industrial evolution known as 'Industry 5.0', which builds upon the achievements of Industry 4.0 (I4.0). This new era emphasizes intangible values such as 'human well-being' and places a priority on people and society over profit. (EIT Digital Professional School 2022) It combines research, innovation, and technology transformation to achieve this objective, applying a more systemic approach to human-centric implementation. (Ivanov 2023)

While still in its early stages, Industry 5.0 recognizes the importance of human-centricity as a core value. It serves as both an innovation catalyst and a driver of change, acknowledging the significant impact of industry transformation on societal transformation. (European Commission 2021) With its implementation workforce roles are beginning to evolve towards being value driven. So far, studies have recorded work re-organizations, personal development enhancements, and enjoyments of greater responsibilities by employees. (Xu et al. 2021a; Ivanov 2023) The implementation of human centricity in industries has emerged as a vital facilitator in achieving socially sustainable manufacturing (Romero et al. 2015). By prioritizing the fundamental needs and interests of individuals, the human-centric strategy shifts the focus from technology-driven progress to one that is fully centered around human and societal well-being (Xu et al. 2021).

As an enabler of change, this report would like to show the technological disruption and evolution human-centricity has had in the industry in recent times through content analysis of secondary data.
To address this research gap, this paper conducts a comparative bibliometric analysis to examine the concept of human-centricity in Industry 4.0, Society 5.0, and Industry 5.0, as well as their relationship with enabling technologies. Additionally, the paper discusses various state-of-the-art initiatives that promote a human-centric approach in these industries and suggests potential areas for further investigation.

2. Methodology

To ensure scientific rigor and minimize bias in the findings, this study employed a systematic approach through the implementation of a Systematic Literature Review (SLR) following the guidelines set by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). By adhering to these established guidelines, the study aimed to enhance the reliability and comprehensiveness of the review process, promoting a rigorous and transparent methodology for synthesizing the available literature.

By adopting this methodology, a thorough overview of the current research was conducted, highlighting key findings and contributions. Additionally, the study suggests potential areas for further investigation. Following the framework proposed by Bardin (2011), a content analysis lens was employed to analyze the designated papers and compile the identified concepts. The StArt program was employed to identify, screen, and determine the eligibility of the included

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studies in this research. For coding and referencing, the Mendeley desktop program and Excel were utilized, ensuring systematic organization and management of the study data. Additionally, Vosviewer was employed for bibliographic analysis, allowing for a comprehensive examination of the literature.

2.1 Design the plan

This research followed Boland, Cherry, and Dickson's (2017) protocol which served as a road map with the following steps:

- design a review plan.
- perform scoping searches to identify research questions, and write protocol
- apply exclusion and inclusion criteria.
- literature search
- conduct a quality assessment; and
- analysis and synthesis
- Discuss the results.

2.2 Define the research question.

Research questions play a crucial role in defining the purpose, objectives, and scope of a study, serving as the guiding force throughout the systematic review process (Sandercock 2012)
Accordingly, we identified the following research questions:
RQ1. What is the state of human centricity in Industry 4.0?
RQ2. What is happening with human-centricity in Industry 5.0 and society 5.0
RQ3. What is the academic state-of-the-art of Human centricity in Industry?

2.2 Defining Inclusion criteria based on PICOSS

The search strategy employed in a systematic review aims to comprehensively identify relevant literature, taking into account feasibility and relevance (Kitchenham, 2004). It involves developing search strings and extracting keywords based on the research questions. To establish inclusion criteria, the PICOSS acronym, representing 'Population', 'Intervention', 'Comparator', and 'Outcome', was utilized as a tool, as suggested by Boland, Cherry, and Dickson (2017). This framework helps in structuring the criteria for study selection and ensures a systematic approach to the review process.

- Population: In this case, population is industries (as a unit of analysis) such as health care, utilities, transportation, and manufacturing industries, and also the humans in society, which includes those in the workforce and those at home.
- Intervention: Industry human centricity, which includes everything done to respect the role, needs, jobs, talents, and rights of humans in industry. It can come in the form of Human-centric product innovations, company policies, role organization, etc.
- Comparator: We would like to see how human-centered the out-going industrial revolution (industry 4.0) was, and compare it with that of Industry 5.0
- Outcome: We would be able to visualize the changing paradigm of industry as value adoption inclines. The recent trends in Industry human centricity and gaining suggestions for future research.
- Settings: Countries or territories
- Study design: Systematic literature review

2.3 Search strategy

After several scoping searches, two bibliographic databases, namely Scopus (Elsevier's database) and Web of Science were searched for relevant published literature. Table 1 details the search syntax used for the databases. The search terms selected for this study encompassed "industry 4.0," "industry 5.0," "society 5.0," and "human-centricity" to capture literature on "human centricity" before and after the introduction of industry 5.0. The inclusion of Society 5.0 was based on its interchangeability with industry 5.0 in scholarly documents within this context, as indicated by Breque et al. (2021). By incorporating these terms, the study aimed to gather relevant literature that addresses the concept of human-centricity in the context of both industry 4.0 and industry 5.0, including their societal implications. Finally, the conduct and reporting of analysis adheres to the detailed step by step guide of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) which is a standardized approach for reporting systematic literature reviews (Boland et al. 2017).

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Table 1. Search syntax

Database	Syntax
Scopus	(TITLE-ABS-KEY("Industry 5.0") OR TITLE-ABS-KEY("Industry 4.0") OR TITLE-ABS-KEY("Society 5.0") AND TITLE-ABS-KEY("Human centric*")) AND (LIMIT-TO (OA,"all")) AND (LIMIT-TO (LANGUAGE,"English"))
Web of Science	(TI=("Industry 5.0") OR TI=("Society 5.0") AND TS=("Human centric*")) AND (OA==("OPEN ACCESS"))

2.3 Search for the literature

After careful refinement and alignment with our research objectives, the search string was defined as: ('Industry 5.0' OR 'Industry 4.0' OR 'society 5.0') AND ('human centric' OR 'human centricity' OR 'human-centric*'). This comprehensive search string captures relevant literature exploring the relationship between Industry 5.0, Industry 4.0, and Society 5.0 with human centricity. The aim is to explore the evolution of "human centricity" across Industry 4.0, Industry 5.0, and Society 5.0 through relevant literature. Society 5.0 is included due to its interchangeability with industry 5.0 in this context. To streamline the search and ensure scientific rigor, keywords like Artificial Intelligence and human-robot collaboration were omitted, as the search string 'industry 5.0' AND 'human-centricity' already encompasses enabling technologies and solutions. Scopus and Web of Science were the primary sources used for comprehensive coverage. The search was not restricted by time and focused on English literature. At the initial search, a total of 207 papers were identified, with 104 retrieved from the Scopus database and 103 from the Web of Science database. Subsequent investigation involved scrutinizing the titles, leading to the exclusion of 112 papers that were not relevant to the subject under study. The database search was conducted on December 12, 2022, resulting in the extraction of a total of 95 records, which were subsequently loaded into the STarT bibliographic software for convenient analysis.

2.4 Apply exclusion and inclusion criteria.

Out of the 95 papers obtained from the search activity, the STarT bibliographic software was able to identify and eliminate 2 duplicate papers. This left behind 93 distinct papers that were available for further analysis and evaluation. Then applying Keshav (2010)'s "first-pass" of the "three-pass" approach, the title, abstract and keywords of the selected records were screened against specified inclusion/exclusion criteria which tallied with our research questions and stipulated objectives in this research. (Boland et al. 2017). For clarity, "first-pass" refers to a quick perusal of a paper's title, abstract, introduction, sectional headings, and conclusion to understand the context, accuracy, and contributions of the study contained therein. (Kolade & Owoseni 2022)

Consequently, 39 papers were excluded as they were not relevant to the topic of 'human-centricity industry', 'society 5.0' and enabling technologies. This left us with 51 papers that were downloaded for further analysis. In order to identify the most pertinent and relevant papers for our study, a comprehensive review of the full text was conducted. As a result of this examination, 32 articles were deemed relevant, as our content analysis confirmed their alignment with our study objectives.
5

2.5 Conduct a Quality Assessment.

We decided not to omit papers that appeared in publications with low to moderate impact factors. Additionally, since Industry 5.0 is relatively new, we chose to include conference papers and book chapters.

Table 2. Research product distribution by topic

AUTHORS	TITLE	YEAR	SOURCE TITLE	CITED BY
(NAHAVANDI, 2019A)	Industry 5.0-a human-centric solution	2019	Sustainability (Switzerland)	194

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(PACE ET AL., 2019)	An Edge-Based Architecture to Support Efficient Applications for Healthcare Industry 4.0	2019	IEEE Transactions on Industrial Informatics	194
(FANTINI ET AL., 2020)	Placing the operator at the centre of Industry 4.0 design: Modelling and assessing human activities within cyber-physical systems	2020	Computers and Industrial Engineering	123
(KADIR ET AL., 2019)	Current research and future perspectives on human factors and ergonomics in Industry 4.0	2019	Computers and Industrial Engineering	97
(KAASINEN ET AL., 2020)	Empowering and engaging industrial workers with Operator 4.0 solutions	2020	Computers and Industrial Engineering	92

2.6 PRISMA diagram

Using the PRISMA flow chart, figure 1 shows the path taken in the search toward paper identification, screening, eligibility and inclusion. (Page et al.2021). The PRISMA flow diagram shows how information moves through the various stages of a systematic review, mapping the number of records that were identified, included, and excluded, as well as the causes of exclusions.

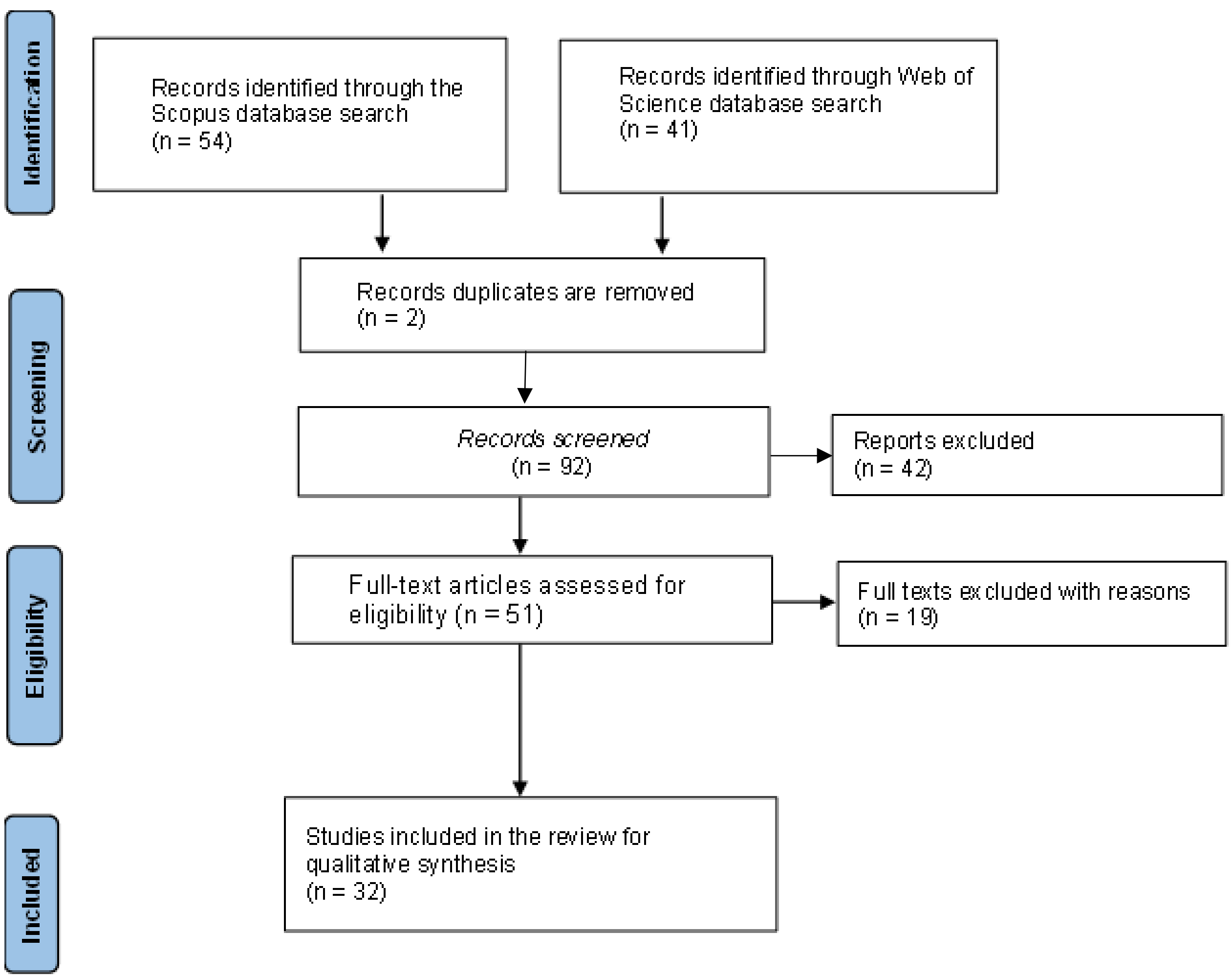

Figure 1. Prisma flow chart

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3.0 Results

The findings of the bibliometric analysis are presented in this section. It begins by looking at the publication types and the subject areas addressed. Following an analysis of the general volume and growth trajectory, the most significant papers, sources, authors, and nations are listed according to the total number of citations.

3.1 Bibliometric mapping/visualization

Figure 3 portrays the overlay visualization of the keywords of the various authors included in the study. Each keyword term is connected by lines called links, which show the relationship between the terms. (van Eck & Waltman, 2021). In the case of bibliographic coupling links) the strength of a link may represent the number of cited references shared by two publications. The importance of an item is indicated by its weight, and the higher the weight the more important the item.

A total of 32 papers were gathered from both Scopus and Web of Science databases. The bibliographic software helped extract 441 keywords from the 32 included papers. The utilization of overlay colors visually represents the publication year of each document in which a keyword appeared. The color spectrum ranges from yellow to purple, with closer proximity to yellow indicating more recent publications, while shades closer to purple signify older publications. The weight of an item is reflected in the size of its label or circle, with larger sizes indicating higher weights. Connections between items are represented by lines, depicting the links between them. The proximity of items in the visualization roughly indicates their level of relatedness, with closer placement suggesting a stronger connection or association. Note: the combinations of the words in our search term, is intended to portray 'human-centricity' in Industry (Industry 4.0, Industry 5.0, or Society 5.0).

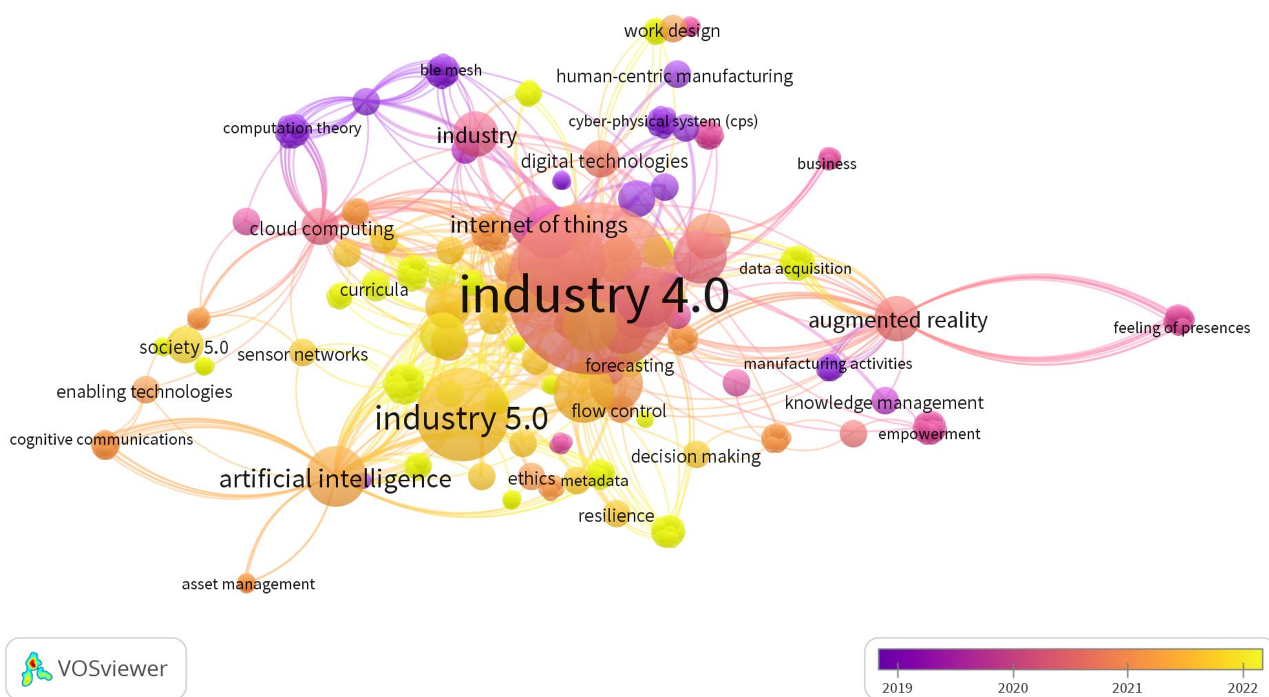

Figure 2. Frequency analysis of keywords

Figure 2. above showcases a frequency analysis of the most frequently used terms in the collective papers. It reveals the enabling technologies and their evolution timelines. The terms in purple like computational theory, cyber-physical systems, and other manufacturing activities had already been in existence as of 2019. By the color coding, we can see

the evolution of Industry 5.0 from the fourth industrial revolution and the innovations coming up. Zooming in, Figure 3 below provides a more focused view with fewer keywords, highlighting the ones that hold greater significance. This approach provides a clearer visualization of the strength of relationships between the keywords.

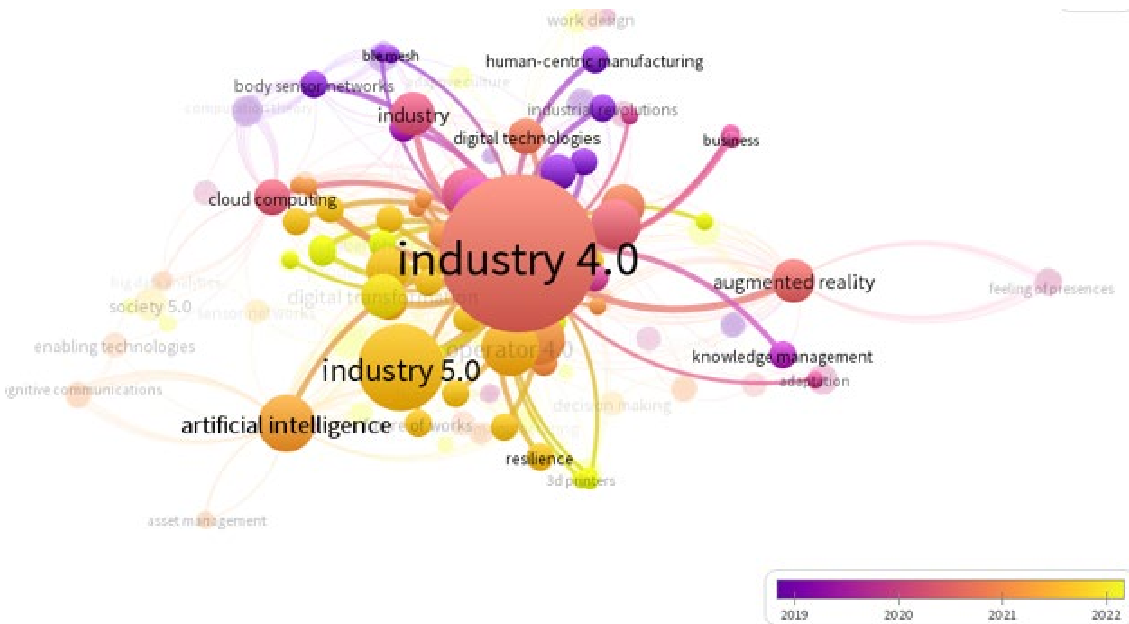

Figure 3. Authors' Zoomed-in keywords Co-occurrence analysis.

Table 3. Showing the keyword occurrences and link strengths

keyword	*occurrences*	*total link strength*
industry 4.0	26	73
industry 5.0	11	22
human-centric	10	29
artificial intelligence	6	13
industrial research	6	20
operator 4.0	6	23
cyber-physical system	5	20
Internet of things	5	12
smart factory	5	16
sustainability	5	12
sustainable development	5	18
augmented reality	4	11
digital transformation	4	10
digitalization	4	11
ergonomics	4	11

Above, in Table 3, you can observe the 'co-occurrence links' and the 'Total link strength'. The co-occurrence between terms represents the number of publications where two terms appear together. The attribute "Total link strength" indicates the overall strength of the co-occurrence links for a specific term in relation to other terms.

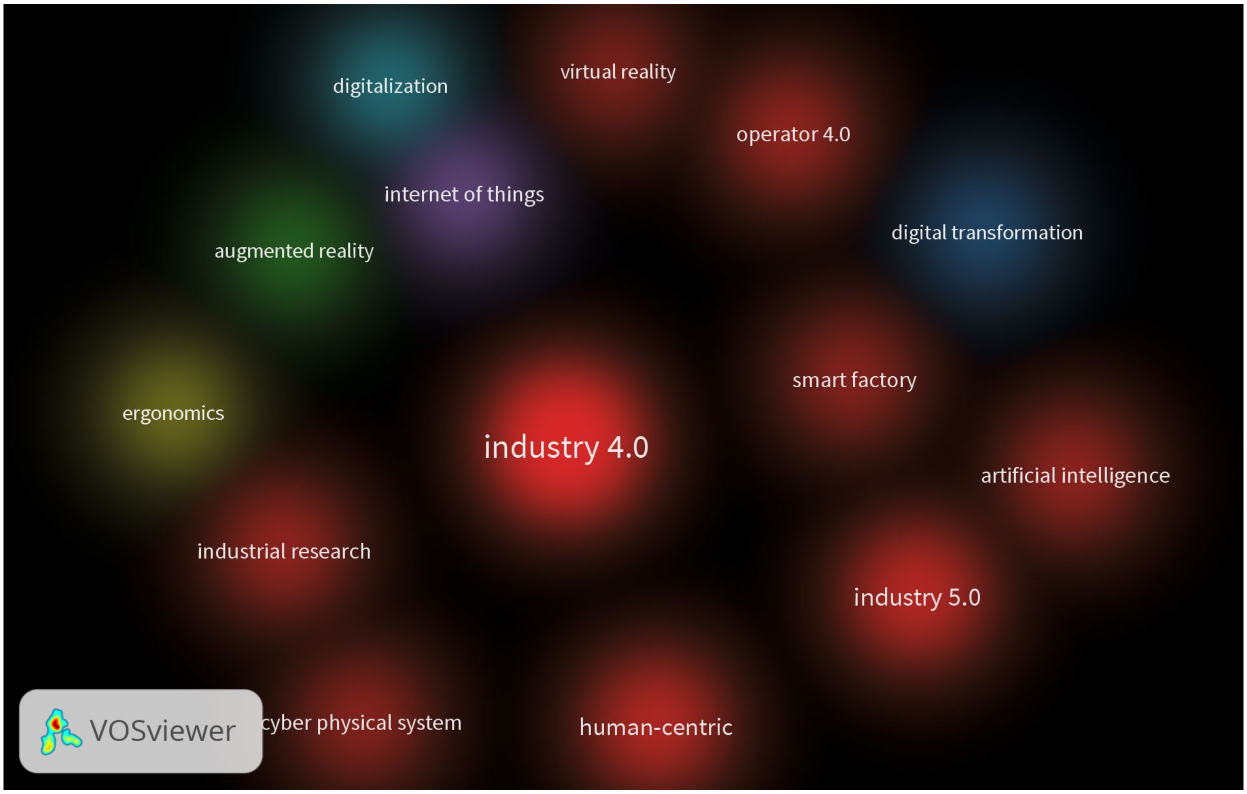

Figure 4. The density visualization map

In Figure 4, a density visualization map is presented, showcasing the distribution and intensity of keywords that highlight the prevailing trends within the realm of industrial revolutions. The heat map effectively illustrates the prominence and significance of these keywords by using varying colors or shades to represent their density. The default color spectrum ranges from blue to green to yellow. Points with a higher number of neighboring items and greater weights among those neighbors will be represented by colors closer to yellow. By visualizing this information in a graphical format, Figure 4 offers valuable sights into the current landscape of industrial revolutions and the key themes that are shaping the field. (Van Eck & Waltman 2021)

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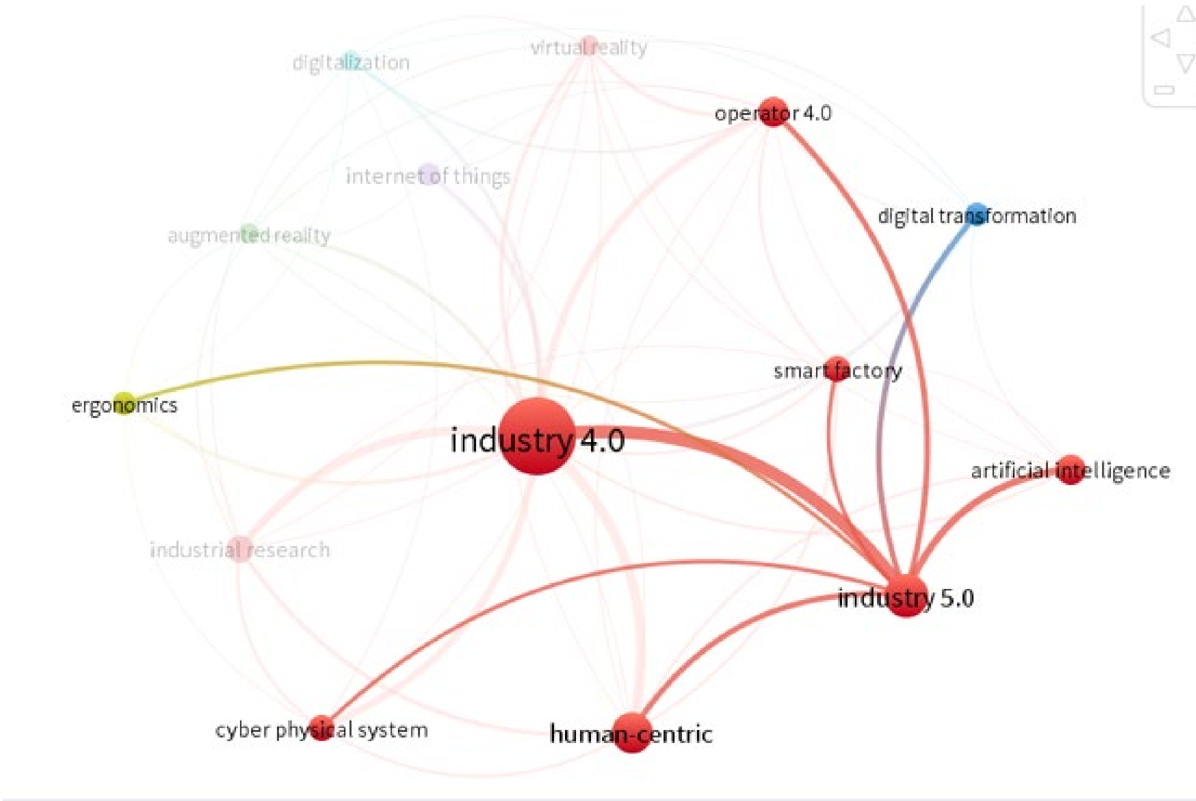

Figure 5. Overlay visualization with respect to Industry 5.0

Overlay visualization with respect to Industry 5.0 in Figure 5, displays items more related to Industry 5.0. Tabulating the keywords in terms of frequency, we observe that aside from the terms 'Human-centric' industry 4.0 and 5.0 occurring the most as depicted by the search terms, it also showcases the enabling technologies that underpin them. Technologies like Artificial intelligence, cyber-physical system, the Internet of things, augmented reality, and concepts. Akundi et al. (2022) concurred with the notion that Artificial Intelligence plays a pivotal role in Industry 5.0.

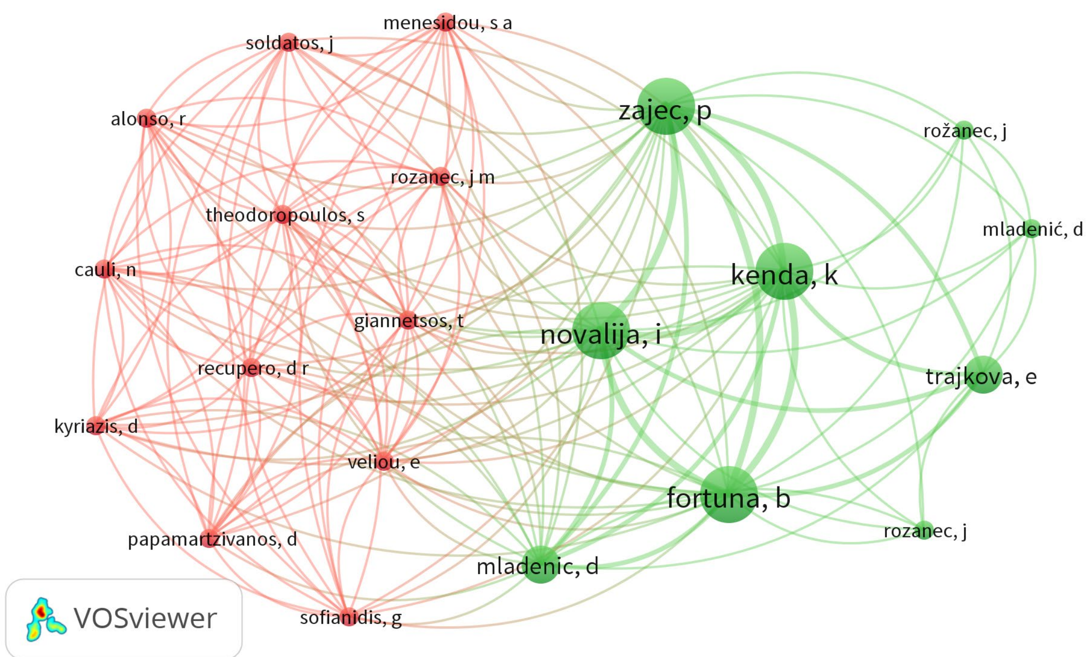

Figure 6. Co-authorship

Figure 6 above presents a visualization of the coauthor ship connections among researchers, highlighting two distinct clusters. Each link between two points represents the number of publications that the two researchers have collaborated on. The weight assigned to each item reflects its significance, with items of higher weight being more prominently displayed in the visualization, while items of lower weight are less emphasized.

Figure 7. Shows Authors in a Word Cloud format. (Source: STarT software for systematic review)

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Figure 7 above shows the author's names in a word cloud. The word cloud lists each author's name, with the size of each name representing how prominent or common that author is in the dataset. This representation offers a quick and intuitive overview of the authorship landscape, allowing the identification of key contributors at a glance.

3.2 Analysis criterion
We found 95 highly relevant studies using the exclusion and inclusion criteria, and we were able to access 51 full-text items. Each item was read and examined, and the important findings of our investigation are presented using a narrative style and are covered in detail by topic.

3.3 Analysis
In exploring human-centricity in Industry, Table 2 provides some quantitative data (total citation and CPY) showing study areas with the highest impact on this topic.

Scholarly literature on the subject of human centricity in industry, in its different forms, has been cited since 2016 commencing from the Engineering sector and then spreading to other disciplines. The bibliometric mapping in figure 1 shows the different subject areas and year of first publication.

Table 4. Number of Subject areas occurrences and citation publication year.

	Number	of publication	publication
Computer Science	34	2018	2022
Engineering	32	2016	2022
Social Sciences	14	2019	2022
Environmental Science	11	2019	2022
Energy	9	2019	2022
Mathematics	8	2019	2022
Business, Management and Accounting	7	2021	2022
Materials Science	7	2018	2022
Chemical Engineering	3	2020	2022
Decision Sciences	3	2021	2022
Physics and Astronomy	3	2020	2022
Economics, Econometrics, and Finance	2	2022	
Agricultural and Biological Sciences	1	2022	
Multidisciplinary	1	2018	

The graphic below shows the number of publications per year of articles in this subject area which is 'human centricity' in industry'. It illustrates how research has evolved, as industries have become more "human-centric". The diagram portrays tremendous progress between 2016 to date.

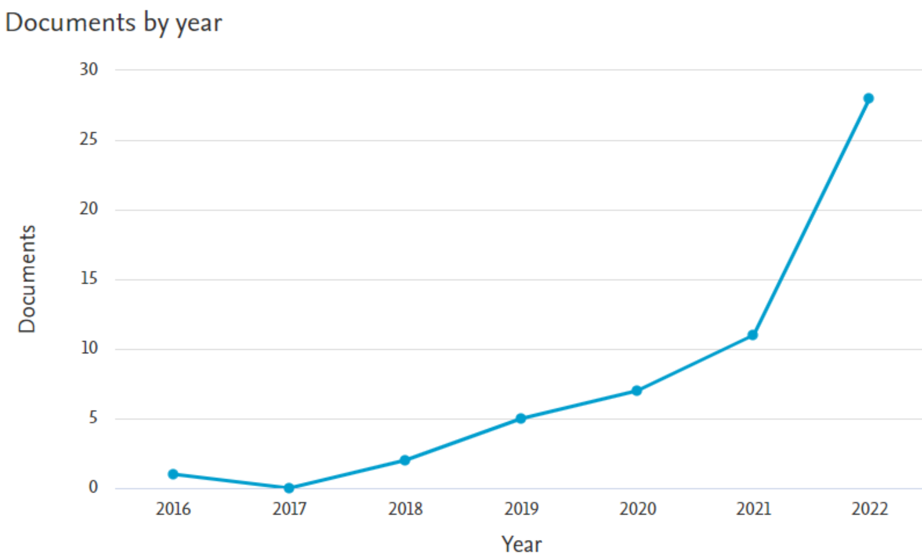

Figure 8. shows documents published by year.

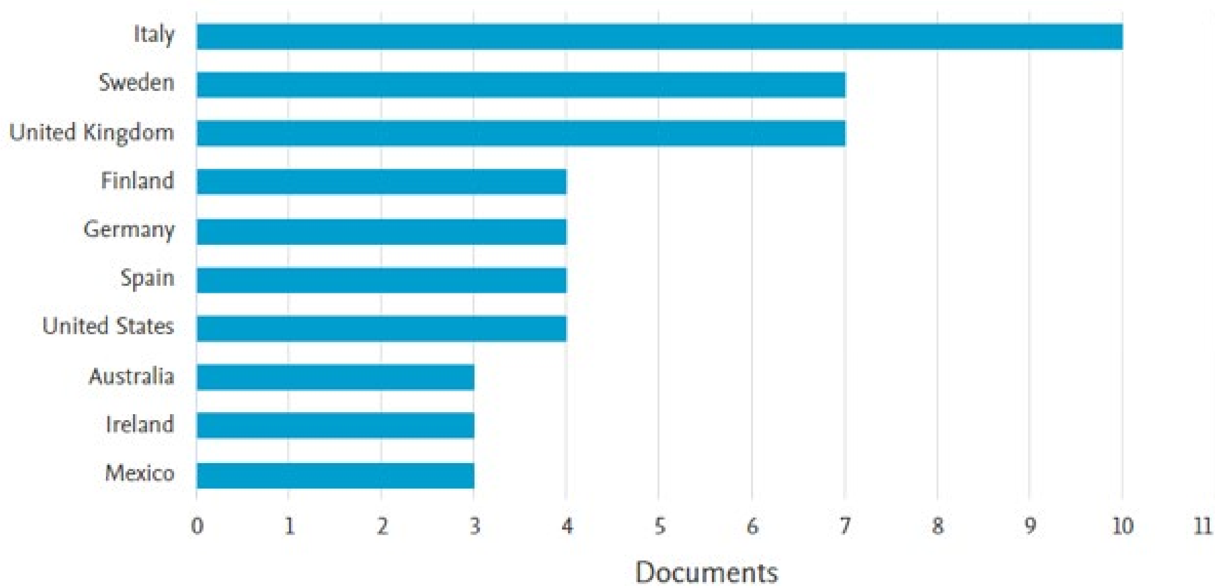

Figure 9. shows documents published by country.

Figure 9 shows the first 15 countries or territories with the highest publications or research in this study area. Italy happens to be the country with the most publications in this research area, followed by Sweden and then the United Kingdom. Via research and innovation, Industry 5.0 complements the existing industry 4.0 paradigm to accelerate the shift to becoming a resilient, sustainable, and human-centric society. (Xu et al., 2021)

4.0 Discussions:

State of Human-centricity in Industry 4.0 (pre-industry 5.0)

The core principle driving the fourth industrial revolution is to create a "smart" industrial sector through the integration of interconnected machines and devices that can communicate with each other and autonomously coordinate their operations throughout their lifespan. (Breque, De Nul, and Petrides 2021) Scholarly literature exists that reaffirms Industry 4.0's consciousness of the value of people's abilities, knowledge, and skills. (Zizic et al. 2022)

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Despite its initial emphasis on a "technology-centered vision," industry 4.0 (Jafari et al. 2022) has actively pursued human centricity through numerous endeavors. Operator 4.0, portrayed as the "operator of the future," is driven by the objective of fostering collaborative and trustworthy interactions between people and robots. (Zizic et al. 2022) Although industry 4.0 may not be regarded as a human-centric endeavor, its contributions in the likes of operator assistance technologies, human-machine cooperation technologies, socio-technical approaches, and work-life balance cannot be ignored. (Xu et al. 2021) While many scholars acknowledge the efforts made in designing human-centric innovations such as human-machine collaborations and AI, the technology transformation of Industry 4.0 did not prioritize giving humans a central role in terms of social sustainability (Zizic et al. 2022). Instead, the focus was primarily on transforming the manufacturing sector by integrating various technologies like artificial intelligence (AI), cyber-physical systems (CPSs), the Internet of Things (IoT), big data, cloud computing, and cognitive computing to enhance productivity and efficiency. (Breque et al. 2021; Huang et al. 2022) Therefore, Industry 4.0 has its limitations as it prioritizes promoting industry efficiency and flexibility over industrial sustainability and worker welfare. (Huang et al. 2022)

The growing adoption of Cyber-Physical Systems in Industry 4.0 transitions is bringing about changes in human work and work organization, generating fresh difficulties and opportunities (Kadir et al. 2019). The industry 4.0 approach to solving human-centricity, sustainability, and resilience issues has been more technical with a consequential perspective (Xu et al. 2021)

While there has been much debate over how technology will affect productivity and industrial growth in the future, Academics and Professionals have focused more on the effects of digital transformation on people's lives, especially those on employment. (Kolade and Owoseni 2022)

Human-centricity in Industry 5.0

The concept of Industry 5.0 presents a unique perspective that underscores the importance of research and innovation in enabling industry to deliver sustainable and enduring benefits to humanity. (Huang et al. 2022) Industry 5.0 is built on the tenets of human-centricity, sustainability, and resilience. It stipulates that for an industry to be a true provider of wealth, it needs to define its genuine mission in terms of social, environmental, and societal concerns. (Breque et al. 2021)

It's been generally concluded according to (Zizic et al. 2022), that primary research goals currently have significantly shifted from just profitability to human-centricity and productivity. Scientists and inventors are already working hard on the Fifth Industrial Revolution idea, built on achieving intensive cooperation and interaction between humans and intelligent machines, robots, and also addressing issues of social sociability in the manufacturing environment. (Majerník et al. 2022) .

Human centricity in industries has become a crucial enabler for attaining socially sustainable manufacturing. Romero et al. (2015) by prioritizing the fundamental needs and interests of man, the human-centric strategy replaces technology-driven progress with one that is utterly human-centric and society-centric (Xu et al. 2021). The result of a review done by (Jafari et al., 2022), showed that compared to Industry 4.0, research on smart logistics in Industry 5.0 now focuses more on how people and technology interact during the digital transformation, with the growing use of adaptive technologies. E.g., collaborative robots, human-machine systems, and human-robot collaboration. Nevertheless, the human-centricity value-driven initiative within the industry, as emphasized by the European Union (Xu et al. 2021), goes beyond merely prioritizing the return and anthropocentricity of human workers. It signifies a shift in the industry paradigm, moving away from a purely techno-centric approach to one that is more focused on the well-being of humans and society at large.

Human centricity plays a significant role in "Industry 5.0" and has led to the emergence of Operator 5.0. (Wang et al., 2022) This concept involves leveraging enabling technologies, as seen in Figure 10 below, to enhance human perception, cognition, and interaction capabilities. (Longo et al. 2020)

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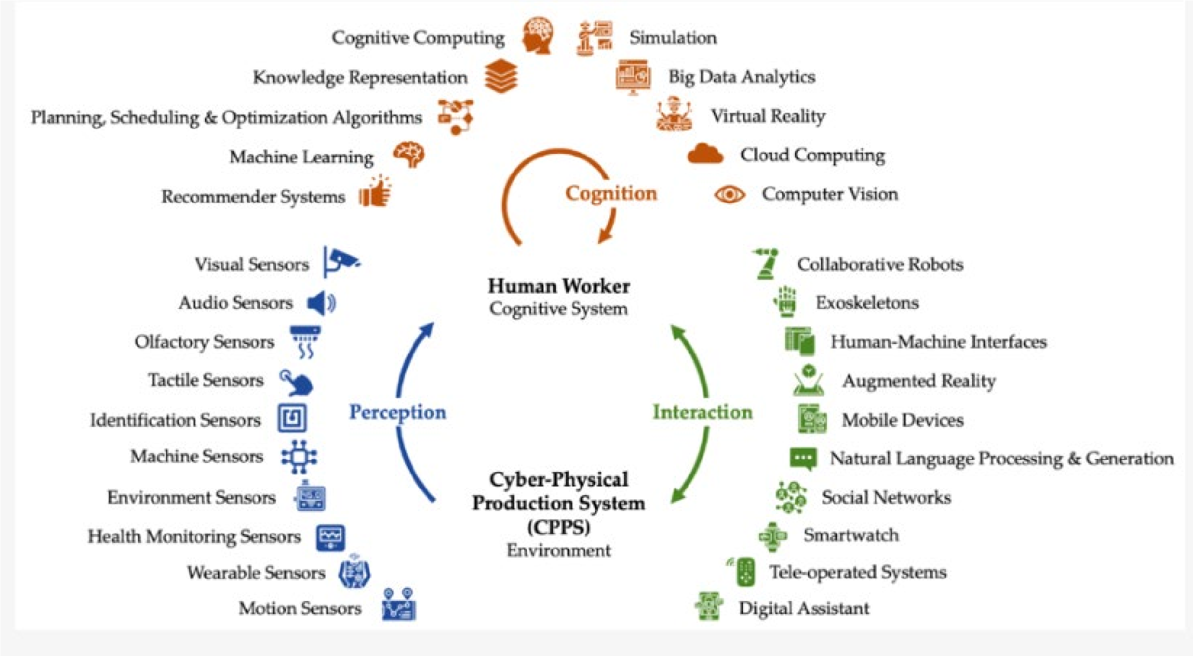

Figure 10. Enhancing Human Capabilities through Technology: Achieving Human – Machine Symbiosis in Industry 5.0 (Longo et al. 2020)

Human-centricity in Society 5.0

Society 5.0 aspires to create a super-smart and human-centric society where every individual can enjoy a high-quality life filled with comfort and vitality. This concept was introduced in Japan to address societal challenges such as an aging population, low birth rates, and a lack of competitiveness. By merging cyberspace and physical space through the utilization of technologies like 5G, Big data, and artificial intelligence, Society 5.0 seeks to achieve a harmonious balance between economic progress and the resolution of social issues. (Narvaez Rojas et al. 2021)

Society 5.0, also known as the Super Smart Society, represents a novel guiding principle for fostering innovation. This paradigm encourages the convergence of physical and cyberspace, enabling robots and AI systems driven by extensive data analysis to undertake or assist in various tasks and advancements alongside human efforts (Fukuyama 2018; Carayannis and Morawska-Jancelewicz, 2022). With a focus on "systemization" of initiatives and services, Society 5.0 embraces a systematic approach that prioritizes the involvement of human beings, including underrepresented groups such as women and young people who traditionally had limited opportunities for active participation. (Carayannis and Morawska-Jancelewicz 2022)

In this concept, every individual in society has a part to play in the innovation process. To provide a safe and secure environment and to advance people's well-being, the Super Smart Society is built on providing concrete, targeted, and personalized just-in-time solutions to the people. (Carayannis and Morawska-Jancelewicz 2022)

Industry 5.0 Vs Society 5.0 (human centricity)

Carayannis and Morawska-Jancelewicz; (2022) refers to Society 5.0 as 'human-centric', Industry 4.0 as 'techno-centric', and Industry 5.0 as 'balanced-techno-human-centric'.
The terms "Society 5.0" and "Industry 5.0" both refer to a fundamental paradigm change in societies and economies that aims to combine economic growth with solving societal and environmental issues as well as the challenges connected with human-machine interactions and talent matching. (Breque et al. 2021; Carayannis and Morawska-Jancelewicz 2022)

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Both Industry 5.0 and Society 5.0 prioritize human centricity as a crucial aspect of their vision. Industry 5.0 aims to unleash human creativity within the industrial sector and transform it into a human-centric, resilient, and sustainable source of prosperity. This approach seeks to address the challenges arising from the current level of industrialization and living standards. In parallel, Society 5.0 envisions the creation of a human-centered, highly intelligent, and efficient society that offers a shared, comfortable, and viable future for all individuals. (Huang et al. 2022)

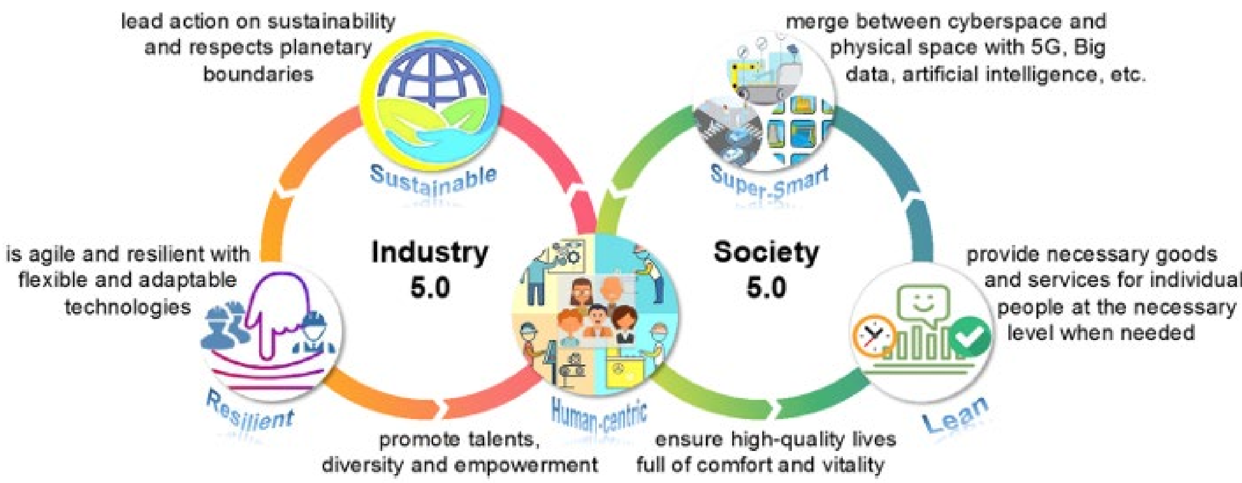

Figure 11. Human centricity a common vision for both Industry 5.0 and Society 5.0. source (Huang et al., 2022)

In essence, while Industry 5.0 and Society 5.0 follow distinct paths to achieve their respective goals, they converge on the principle of human centricity and strive to strike a balance between economic progress and societal concerns. (Huang et al. 2022)

4.1 The academic state-of-the-art on Human centricity innovations

Balanced automation system:

The principle underlying the balanced automation system emphasizes the importance of human autonomy and the symbiotic relationship between humans and automation. Adaptive automation in human-automation-symbiosis is the concept of having automation and robots dynamically and momentarily adapting to human cognitive and physical demands. (Romero et al. 2015; Tzafestas 2006) The Next Generation Balanced Automation Systems (NGBAS) is a reference architecture with a human-centered approach. It is designed to be adaptive, considering various factors in the operating environment, such as the passage of time, performance degradation, and operator limitations due to factors like age, disability, and lack of expertise. The main objective of NGBAS is to optimize productivity by maximizing the capabilities of operators within these constraints.

Three classes of automation invocation strategies include the critical-event strategy, measurement-based strategies, and modeling-based strategies. (Romero et al. 2015)
For instance, a senior operator can benefit from adaptive automation in two ways: either by increasing automation to make up for age-related limitations and maintain the physical and cognitive quality of job performance or by reducing the level of automation, upon request, to give the senior operator a "craftsman's experience" and boost job satisfaction.

Human-centric Assembly
Improved overall productivity and an ergonomic working environment are created when Human-Robot collaboration blends the robot's strength, repeatability, and accuracy with the flexible, adaptable, and high-level cognition of the human being. (Wang 2022)

As a perfect futuristic perspective of a Human-Robot collaboration blend, (Wang 2022) conceptualized Human-centric Assembly, where humans are augmented physically and mentally by the brain (sense enabled) robotics and by four Enhanced Human Abilities (EHAs), to EASE the human's TASK. The human abilities are enhanced by the 4 EHAs which are augmented robots, mixed reality, cognitive systems, and co-intelligence as seen in the diagram below, to 'EASE' which stands for Energize, Advice, Support, and Empower, a human operator physically and intellectually. With the operator's human abilities heightened to become a super operator, he can apply his knowledge to be more productive at assembly tasks. (Huang et al. 2022)

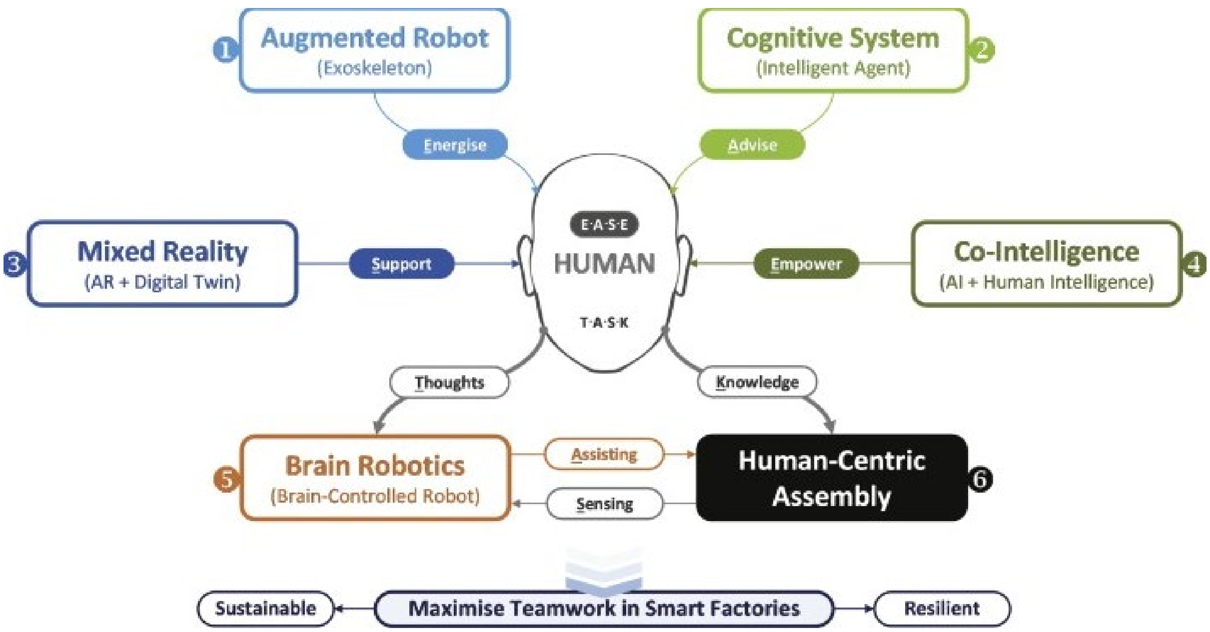

Fig 12. Human centric Assembly Operations in Future Factories (Wang, 2022)

HCPS – Human Cyber-physical system

National Institute of Standards and Technology (NIST) defines "Cyber-Physical Systems or "smart" systems as co-engineered integrated networks of computational and physical components (Fantini et al., 2020). Ushered in by the fourth Industrial revolution (Saniuk & Grabowska, 2022) defines Cyber-Physical Systems (CPS) as integration of operational technologies and information and communication technologies (ICT) in businesses and supply chains, providing additional capabilities to physical systems (Wang, Törngren, & Onori, 2015; Fantini et al., 2020).

In the realm of traditional cyber-physical systems (CPS), where manual labor is largely replaced by robots and machines, the primary focus of research has been on enhancing the autonomy, creativity, and responsibility of intelligent machines. However, this emphasis has inadvertently overlooked the significance of human involvement in critical decision-making processes. (Wang, Zhou, et al., 2022) Romero and Stahre (2021) argues it was originally, designed in such a way as to entirely replace humans with autonomous machines and devices assisted by artificial intelligence technologies.

Whether in the context of Industry 5.0 or Society 5.0, the integration of cyberspace and physical space stands as a crucial enabling technology. Given that humans possess remarkable creativity, adaptability, and agency within the system (be it industry or society), their active participation in the cyber-physical interaction loop and decision-making process becomes pivotal, ultimately leading to the development of human-cyber-physical systems (HCPS). (Huang et al., 2022; Zhou et al. 2019)

With industry adoption of the new industrial revolution, the 'Human cyber–physical system' (HCPS) has become a novel strategy for designing future industries. The humanization of the technically built environment of CPS was one of the initial elements in the transition from Industry 4.0 to Industry 5.0 (Saniuk & Grabowska 2022) The HCPS

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according to (Fantini et al. 2020) is a highly effective collaboration of people, technology, and information systems working together and connecting the physical and the digital ("cyber") world CPS.

By integrating humans, social networks, and physical processes, cyber-physical systems (CPS) combine various elements. The advancement of sensing, actuation, embedded computing, and artificial intelligence (AI) enables the emergence of human-cyber-physical systems (HCPS). HCPS not only facilitates a harmonious collaboration between humans, machines, and intelligence but also expands its applicability to a broader range of industries and healthcare sectors, offering more sophisticated use cases. (Wang, Zhou, et al. 2022)

Human-machine collaboration

By fusing workflows with intelligent systems, the Fifth Industrial Revolution is connecting humans and machines to better leverage human creativity and brainpower. (Nahavandi, 2019) Human-machine collaboration is a growing movement to reintegrate human workers into factory settings, working alongside collaborative robots (Cobots). This symbiotic relationship capitalizes on the unique strengths of both humans and robots - human creativity and general intelligence, combined with robot precision, repeatability, and enhanced perception facilitated by advancements in artificial intelligence technologies. (Asad et al. 2023)

By combining the skills of humans and robots in a shared workspace, a solution that has emerged to solve the currently growing demand for personalized products, Human-robot collaboration. (Segura et al. 2022) according to (Nahavandi, 2019) The new industrial revolution has ushered in the so-called "cobot" generation of robots, which are robots that can be turned into ideal human companions. These robots are said to have a human touch as they can be preprogrammed or designed to quickly pick up on tasks. They are safe to be around, as they are built to be people aware, and to watch and learn from their human counterparts. (Saeid Nahavandi 2019b; Wanasinghe et al. 2021). Safety measures are implemented to facilitate secure human-robot collaboration, such as controlling the velocity of the tool center point (TCP), limiting robot power and force, employing collision detection and avoidance, incorporating protective stop functions, and designing ergonomically optimized robots and workspaces. (Asad et al. 2023) (Kaasinen et al., 2022) regards collaborative robots as artificial intelligence (AI) assistants and Smart machine companions on the factory floor.

The future of human-machine co-working has raised concerns related to various psychological aspects, including the lack of social interaction, skepticism towards learning robots, the impact on the human workforce, and the potential for human-robot competition, among other factors. (Demir et al. 2019).

4.2 Other Human-centered argumentative designs:

Utilizing Wearable Technology for Health Monitoring and Movement Tracking of Workers.

Wearable technology, like smart garments, wristbands, and smartwatches, gathers workers' health data and tracks movements. Prototypes monitor arm and finger movements, along with heart rate variability, to assess task-related stress during manual assembly. Handling and processing substantial data is necessary, so the solution incorporates big data analytics methods. (Longo et al. 2020)

Utilizing VR training solutions based on simulations to enhance learning and augment workers' cognitive capabilities.

With the growing complexity of production environments, traditional training methods have become obsolete. As a result, there has been the need to integrate Modeling & Simulation methods with Virtual Reality to create immersive training environments for personnel.

Enhancing the interaction capabilities of workers through the implementation of intelligent voice-enabled digital assistants in factory settings.

The advent of voice-enabled digital assistants is revolutionizing human interaction with Cyber Physical Systems (CPPS). In the future, each autonomous and cooperative component of a CPPS will have the capability to engage in digitally generated voice-based interactions with human workers, leading to the emergence of the Social Smart Factory. (Longo et al. 2020)

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4.3 Areas for further research.

Despite the thoughtful consideration given to the concept of human-centricity, its applicability and technical implications in industry have yet to be substantiated, as noted by Lu et al. (2022). Further research is needed in the field of human-centricity within industry, particularly focusing on studies related to mass personalization. This area of investigation explores the integration of human-machine empathy and coevolution, aiming to enhance both human well-being and system productivity. Additionally, given the presence of techno-social dilemmas, automation risk and numerous stressors in today's world, increasing attention is being directed towards the sustainability of human energy on the factory floor.

5. Conclusion

In summary, this report presents a comprehensive analysis of the evolution of human-centricity in industries, covering the transition from industry 4.0 to the current developments in Society 5.0 and Industry 5.0. It provides a concise overview of the significant changes and advancements that have occurred, emphasizing the increasing focus on placing humans at the forefront of industrial progress and addressing societal needs. Through bibliographic analysis, valuable insights were gained regarding the technological trends and enabling technologies associated with human-centric Industry 5.0. The report also highlights the countries with the highest research publications and notable authors in this field. Additionally, it discusses state-of-the-art human-centric innovations and the importance of human-centered augmentative designs.

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