International Journal of Advances in Data and Information Systems
Vol. 5, No. 2, October 2024, pp. 136~156
ISSN: 2721-3056, DOI: 10.59395/ijadis.v5i2.1336

Industry 5.0 Research in the Sustainable Information Systems Sector: A Scoping Review Analysis

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Article Info

Article history:

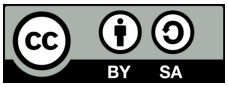
Received Jul 31, 2024
Revised Sep 09, 2024
Accepted Oct 30, 2024

Keywords:

Industry 5.0
Scoping Review
Human-Centric
Resilience
Sustainability

ABSTRACT

Industry 4.0, centered on cyber-physical production systems, has been criticized for prioritizing profit over social and environmental concerns. In contrast, Industry 5.0 emphasizes AI efficiency while promoting human-centric, resilient, and sustainable approaches, integrating economic, social, and environmental systems. Previous research has often focused solely on conceptual frameworks and technologies, overlooking Industry 5.0's sector-specific impacts. This study addresses that gap by conducting a scoping review to map research findings, identify trends, and highlight knowledge gaps and future research opportunities. By systematically analyzing literature from the Scopus database (2016-present), the study refined a large dataset to focus on Industry 5.0's relevance. The analysis revealed significant attention to sectors like Industry and Producer Services, while Agriculture and Retail, particularly natural resource-based sectors like agriculture and fisheries, are often neglected. Key findings indicate that Industry 5.0 is likely to be driven by the industrial sector, followed by product services and financial industries. The study also highlights the strong connection between IoT and AI in optimizing operations with real-time data and automation and identifies blockchain as a promising technology for enhancing transparency and security, despite existing implementation challenges. This research not only serves as a foundational record of Industry 5.0's implications across various sectors but also provides valuable insights into its role in Information Systems (IS). It lays the groundwork for future exploration of Industry 5.0 in diverse sectors and industries.



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1. INTRODUCTION

Industry 4.0 revolutionizes manufacturing with Cyber-Physical Production Systems [1], [2], [3]. However, it has faced criticism for prioritizing profit over social and environmental concerns [3]. In response, Industry 5.0 addresses these issues by integrating human and environmental considerations with AI efficiency, fostering a symbiotic relationship between economic, social, and environmental systems [4], [5], [6]. Envisioned as the future of manufacturing, Industry 5.0 emphasizes a personalized, autonomous, and environmentally friendly era of industrialization [7]. While various studies have analyzed Industry 5.0's early technology enablers and conceptual

frameworks, there is a notable gap in understanding its impact across different industrial sectors [1]. This lack of coverage means that only a small portion of publications discuss Industry 5.0's application within specific industries. This study aims to fill this gap by providing a holistic overview of Industry 5.0's impact across various sectors, identifying areas where its integration is lacking, and offering recommendations for future research.

1.1. Definition of Industry 5.0

Understanding Industry 5.0 requires understanding of previous industrial revolutions [8]: Industry 1.0 dawned with the advent of steam engines, while Industry 2.0 was propelled forward by the harnessing of electricity. Subsequently, Industry 3.0 saw the beginnings of partial automation through computerization. Industry 4.0 marked a significant leap, introducing Cyber-Physical Systems driven by artificial intelligence, cloud computing, the Internet of Things, and cyber-physical integration. Now, Industry 5.0 steps forth to address the societal and environmental concerns inherent in this evolutionary journey. Emphasizing human-centricity, sustainability, and resilience, Industry 5.0 carefully weighs societal and environmental factors in its operations.

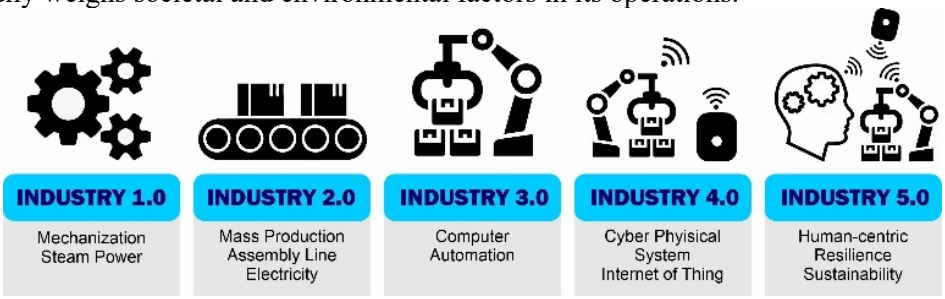

Figure 1 Stage of Industrial Revolution

The European Union in 2020 vision of Industry 5.0 prioritizes worker prosperity and environmental sustainability. [9] views industry 5.0 as a manufacturing paradigm placing worker well-being at the forefront, emphasizing collaboration between humans and machines. In [10] emphasizes the synergy between humans and machines, fostering personalized manufacturing systems. Conversely, [6] view Industry 5.0 primarily as a business concept leveraging intelligent manufacturing systems for enhanced efficiency. Moreover, Industry 5.0 underscores the central role of humans and expands its focus to encompass sustainability and resilience [4], [9]. Despite its lofty aspirations, the tangible impact of Industry 5.0 remains predominantly within the realm of manufacturing [11]. In essence, existing literature aligns in recognizing human-machine collaboration as pivotal to Industry 5.0, advocating for a human-centric approach that promotes economic, social, and environmental progress and sustainability.

1.2. Previous Review Articles on Industry 5.0 Literature

Table 1 provides a comprehensive overview of review articles on Industry 5.0, categorized by authors, titles, objectives, approaches, contexts, and enabling technologies. These articles are primarily divided into two thematic areas: the "Concept and Idea" category, which explores foundational principles such as human-centricity, resilience, and sustainability [1], [12], [13], and the "Enabling Technology" category, which highlights crucial technologies like edge computing, AI, blockchain, digital twins, IoT, big data analytics, cobots, and 6G [10], [14], [15], [16], [17]. While various review methodologies—such as Textual Narrative Synthesis [18], Narrative Reviews [19], Meta-Summary [20], and Meta-Narrative Reviews [21]—have been employed, the existing literature tends to focus heavily on conceptual frameworks and enabling technologies through methods like Narrative Synthesis and Meta-analysis. This concentration on conceptual and technological aspects has led to an underrepresentation of the practical implications and sector-specific impacts of Industry 5.0, particularly concerning its resilience dimension [10], [22]. The resilience aspect of Industry 5.0, a key component that ensures systems can withstand and adapt to disruptions, is often overshadowed by discussions centered on technological advancements and human-centric approaches [1], [3]. For instance, while the integration of advanced technologies such as AI and IoT is frequently highlighted,

the literature inadequately addresses how these technologies can enhance the resilience of industrial systems in practice. This gap is critical because resilience is a cornerstone of Industry 5.0's promise to create more adaptable, robust, and sustainable industrial systems. Addressing this gap, our study adopts a scoping review method to map and synthesize research findings across various industrial sectors. This approach not only identifies emerging trends and knowledge gaps but also critically examines underexplored areas, such as the resilience of Industry 5.0 systems. By doing so, our research aims to provide a more holistic understanding of Industry 5.0, highlighting the need for further exploration of how its principles and technologies can be effectively integrated to enhance the resilience of industrial sectors.

Table 1. Review Articles on Industry 5.0.

Source	Title	Objective	Approach	Findings	Context
[23]	Industry 5.0—The Relevance and Implications of Bionics and Synthetic Biology	Provides the literature review for the certain technology in bionics and sysnthetic biology	Narrative Review	Provides a general taxonomy in which the development of bioengineering is classified in five stages (DNA analysis, bio-circuits, minimal genomes, protocells, xenobiology) from the familiar to the unknown, with implications for safety and security, industrial development, and the development of bioengineering and biotechnology as an interdisciplinary field.	Enabling Technology
[13]	Is Industry 5.0 a Human-Centred Approach? a Systematic Review	Analyses and clarifies the concepts and ideologies of Industry 5.0 and its respective technologies as well as the strategies of human centricity, with the aim of achieving sustainable and resilient systems, especially for the worker	Narrative Review	The idea of the concept of Industry 5.0 is the centralization of humans in production systems, but the studies carried out focus a lot on technological advances and the development of technologies for this purpose	Concept and Idea
[24]	Industry 5.0: Prospect and Retrospect	Discusses key enablers, the future implementation path, potential applications, and challenges of realistic scenarios of Industry 5.0.	Meta-analysis	Cross-dimensional aspect and factors about the future of industry 5.0	Concept and Idea
[25]	Digital Transformation Towards Industry 5.0: a Systematic Literature Review	Literature Review of industry 5.0	Meta-analysis	Though the transition of Operator 5.0 is inevitable, Industry 4.0 technologies are not ready with sufficient human factor integration	Enabling Technology
[3]	Industry 4.0 and Industry 5.0—Inception, Conception and Perception	To see the transition happening from industry 4.0 to Industry 5.0 with seeing enabling technology and the journey took place	Textual Narrative Synthesis	Displays the meaning, characteristics, journey of industrial revolution and what things wait ahead.	Concept and Idea
[22]	Industry 5.0 and Triple Bottom Line Approach in Supply Chain Management: The State-of-the-Arts	Identifies which technologies, favor sustainable emerging practices considering the triple bottom line (3BL) perspective	Textual Narrative Synthesis	Provides a comprehensive overview of the use of digital technologies to favor sustainable emerging practices in SCM considering environmental, economic and social dimensions.	Enabling Technology
[10]	Industry 5.0: a Survey on Enabling Technologies and Potential Applications	Provides a survey-based tutorial on potential applications and supporting technologies of Industry 5.0.	Survey-Based	Supporting technologies for Industry 5.0, such as edge computing, digital twins, collaborative robots, Internet of every things, blockchain, and 6G, etc.	Enabling Technology
[1]	Industry 5.0-a Human-centric Solution	Introduces the concept of Industry 5.0, where robots are intertwined with the human brain and work as	Meta-narrative	This article outlines a number of key features and concerns that every manufacturer may have about Industry 5.0. In addition, it presents several developments achieved by	Concept and Idea Enabling Technology

Source	Title	Objective	Approach	Findings	Context
		collaborator instead of competitor.		researchers for use in Industry 5.0 applications and environments. Finally, the impact of Industry 5.0 on the manufacturing industry and overall economy is discussed from an economic and productivity point of view	
[17]	Industry 5.0 and its technologies: A systematic literature review upon the human place into IoT- and CPS-based industrial systems	Constructs a structure about existing knowledge of Operator 4.0	Metasummary	Literature Review on enabling technologies and the grounding concept in Internet of Things (IoT) & Cyber–Physical Systems (CPS)	Enabling Technology
	This Study	*Categorize literature according to the nature of the publications on Industry 5.0, and map out sectors to illustrate the influence of Industry 5.0.*	*Scoping Review*	*Categorize previous literature review and mapping sectors that influenced by Industry 5.0*	*Industry 5.0 influences*

2. RESEARCH METHOD

This study adopts a scoping review methodology due to its capacity for thorough data extraction, providing a comprehensive overview of the field and previous research endeavors [26]. A scoping review is a type of systematic literature review that aims to map the existing literature on a particular topic. This approach is often conducted to identify key concepts, sources of evidence, and research gaps in a broader field. Unlike a traditional systematic review, a scoping review does not typically assess the quality of the included resources. Instead, it provides an overview of the existing literature [27].

One of the key characteristics of a scoping review is its inclusive approach towards literature. Unlike systematic reviews that have stringent inclusion criteria, scoping reviews aim to encompass a wide range of sources, including diverse study designs and types of evidence [28]. Rather than focusing on synthesizing the evidence, a scoping review aims to systematically map out the existing literature, identifying the range and nature of sources available on a particular topic. This process helps in visualizing the breadth and depth of the research landscape [26]. Another crucial aspect of a scoping review is its emphasis on identifying knowledge gaps and areas that require further exploration [29]. By comprehensively mapping the literature, researchers can pinpoint areas where further primary research or systematic reviews are needed. By outlining the current state of knowledge within a specific field, a scoping review sets the stage for future research endeavors. It provides researchers with a comprehensive understanding of the existing literature, enabling them to make informed decisions about the focus and direction of their own research projects [26].

This approach is particularly appropriate for Industry 5.0, which is still in its early stages of development. Empirically, the earliest references to Industry 5.0 in Scopus trace back to 2016, primarily with implicit mentions [1], while explicit discussions emerged in 2019 [1]. Therefore, a scoping review offers an approach to comprehensively map the existing literature, considering the state, volume, and characteristics of early research in this field [30].

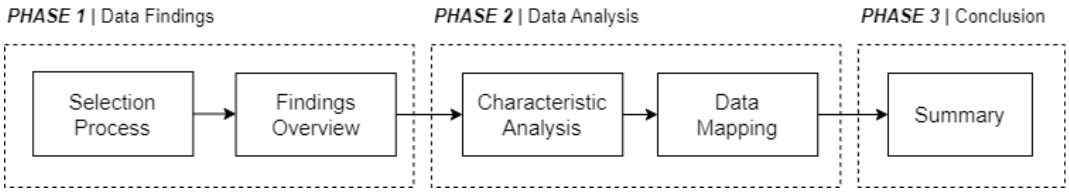

Figure 2 Research Framework

Figure 2 illustrates the research framework of this study, adopting the scoping review research framework outlined by [26]. The framework consists of three main phases: (1) data findings, (2) data analysis, and (3) conclusion. The data findings phase involves the article selection process and an overview of the findings. The data analysis phase includes characteristic analysis and data mapping. The conclusion phase summarizes the results of the study.

In Phase 1, data were sourced from the Scopus Database, focusing on Industry 5.0, with duplicate removal and exclusion of non-English articles. Scopus was chosen as the sole database for data collection in this study due to its extensive coverage of peer-reviewed literature, particularly in fields relevant to Industry 5.0. Scopus offers a broad and diverse collection of academic sources, ensuring that the literature on emerging topics like Industry 5.0 is well-represented. However, relying exclusively on Scopus introduces certain limitations, such as the potential exclusion of relevant studies indexed in other databases or unpublished work not covered by Scopus.

Phase 2 involved data analysis, where articles were characterized descriptively and categorized into Conceptual, Implementation, or Review articles. A conceptual article explores abstract ideas foundational to principles and beliefs [31]. An implementation article focuses on the systematic adoption of research findings into practice to enhance quality and effectiveness [32]. Documents identified as reviews, either explicitly or implicitly, are categorized as review articles. The authors carefully examine each citation's abstract, and if needed, the full article, to confirm its classification. Individual articles were scrutinized, discussing sectors or topics covered. Data were further analyzed using Microsoft Excel, RStudio, and VOSviewer software to explore and present insights from different perspectives.

Finally, in Phase 3, the findings were summarized, highlighting key insights and suggesting future research directions based on the analysis.

3. RESULTS AND DISCUSSION

3.1. Literature Selection Process

The initial search was conducted on November 7th, 2023, utilizing electronic database SciVerse Scopus (multidisciplinary; 2016 – present). To maintain focus, only one database was selected, allowing for a more specific and rigorous analysis. The search query employed a general term related to Industry 5.0, tailored to meet the research's requirements.

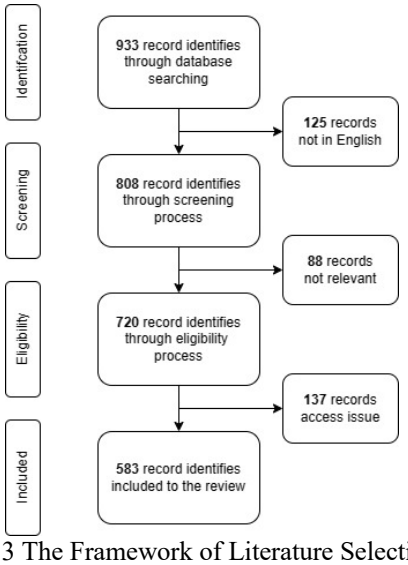

Figure 3 The Framework of Literature Selection

All citations were managed using Mendeley Reference Manager 2.107.0 software. Duplicate citations were manually identified and removed. Subsequent screening of titles and abstracts, as well

as characterization of full articles, was performed manually within Mendeley. Articles not in English were excluded, resulting in 808 citations after screening. Eligibility was then assessed based on whether the abstract and title provided information relevant to Industry 5.0, either within specific sectors or at a conceptual level. Following this criteria, 720 citations remained. Accessibility limitations restricted access to some journals, reducing the number of citations to 583. The flowchart portraying the framework of the research is portrayed in Figure 3.

3.2. Extant Articles Analysis

Figure 4 portrays an overview snapshot of the evolving academic discourse on Industry 5.0. As the figure shows, the number of articles has been increasing steadily from 2018 to 2022, this shows a growing interest in the topic of Industry 5.0. Furthermore, the number of conference papers peaked in 2022 with a sharp decline in 2023. Then, the number of reviews is less compared to articles and conference papers, but there is a noticeable increasing trend. It indicates a growing need for critical evaluation and synthesis of the existing literature.

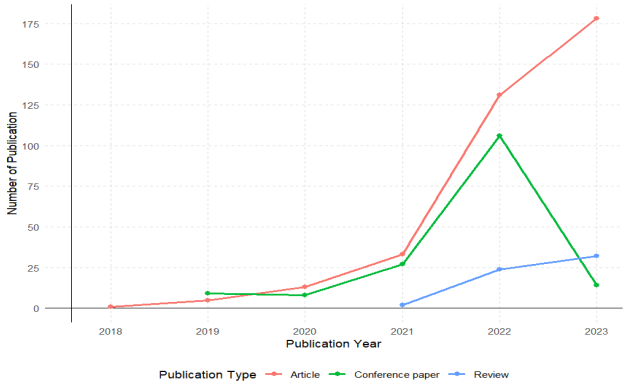

Figure 4. Industry 5.0 Articles by Publication Type

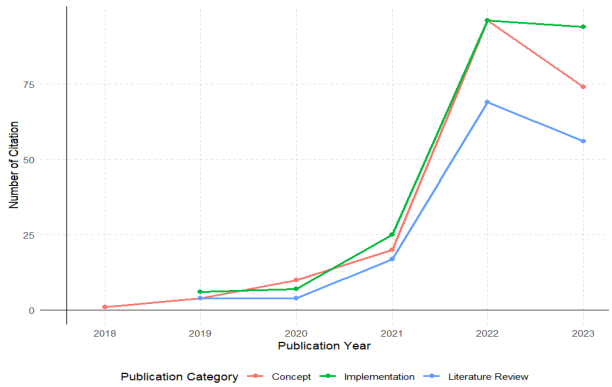

Figure 5. Industry 5.0 Citation Article by Publication Category

Furthermore, after gathering all relevant literature, the document will be divided into three categories - Conceptual, Implementation, and Review. A conceptual article deals with abstract ideas and is a fundamental building block for underlying principles, thoughts, and beliefs [31]. An Implementation Article Journal, on the other hand, deals with the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice to improve quality and effectiveness [32]. Finally, if the document explicitly or implicitly states that it is a review, then it will be categorized as a review article. Additionally, the authors meticulously examine each citation's abstract, and if necessary, the entire article, to verify its category. In the figure 5, we observe a significant increase in the number of citations for Industry 5.0 articles across all publication categories. This indicates that citations for Industry 5.0 are rapidly

increasing in every possible type of article. The apparent decrease in 2023 does not signify a reduction in citations but rather reflects the fact that the year 2023 was not yet complete when the authors finalized this article.

3.3. Sector Level Analysis

Drawing from [33] economic sectors are divided into seven activities: Agriculture (A), Large Heterogeneous Industries (I), Distribution (D), Retail (R), Consumer Services (C), Producer Services including financial (P), Government including healthcare and Education (G). This classification serves as the basis for the mapping of the industrial sectors discussed by Industry 5.0 research.

Tab. 2. Economic Sectors Exposed to 5.0 Research

Sectors	Industries	Sectors	Industries
A	Agriculture & Fishery	*I*	Electricity & Water Supply
A	Natural Resources	*I*	Building and Construction
I	Food and Beverage Industry	*D*	Distribution over land
I	Tobacco Industry	*D*	Distribution over water
I	Textile Industry	*D*	Distribution by air
I	Clothing Industry	*D*	Distribution services
I	Leather Goods Industry	*R*	Retail
I	Timber Industry	*C*	Wholesale Trade
I	Paper Industry	*C*	Hotels, Restaurant & Bars
I	Publishing and Reproduction	*C*	Real Estate Intermediates
I	Oil Processing Industry	*C*	Movable est. intermed
I	Chemical Industry	*P*	Telecommunication and post
I	Synthetic and Rubber Industry	*P*	Banks
I	Glass and Ceramic Industry	*P*	Financial Services
I	Primary Metal Industry	*P*	Computer-Services
I	Metal Production Industry	*P*	Research & Development
I	Machinery Industry	*P*	Other Business Services
I	Computer Industry	*G*	Government
I	Electronics Industry	*G*	Education
I	Audio and Telecom. Industry	*G*	Healthcare
I	Car Industry	*G*	Environment Services
I	Transport Industry (excl. cars)	*G*	Unions
I	Furniture Industry	*G*	Culture, Sports & Recreation
I	Recycling Industry	*G*	Personal Services

Figure 6 illustrates the distribution of sectors impacted by Industry 5.0 showing the total share of percentage based on publications volume relative to publications from other sectors. It appears that the Industrial sector (I) is predominant, with 45.38% of the total percentage. The Producer Services sector including finance (P), and the Government sector including healthcare and education (G), follow with 22.43% and 20.21%, respectively. Conversely, the Distribution (D), Agriculture (A), Retail (R), and Consumer Services (C) sectors present significantly smaller shares, at 5.82%, 2.57%, 2.23%, and 1.37% correspondingly.

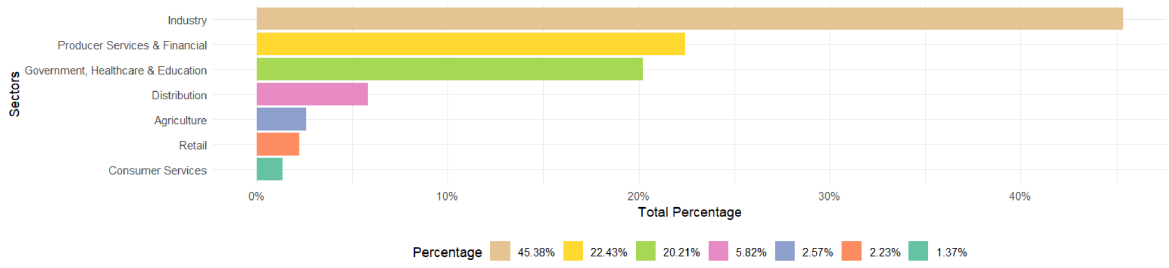

Figure 6 Research Share in Industry 5.0 Across Various Industrial Sectors

3.4. Industry Level Analysis

In [34] defines an industry as a range of economic activities producing goods or services within a specific field. Moreover, [35] elaborates that the term "industry" refers to groups of companies that perform similar or related economic activities, utilizing similar resources, technology, and methods to deliver products or services to the market. Based on the definitions mentioned above, the authors conclude that the term "industry," in the context of this paper, refers to specific activities of an economy involved in the production of goods or services within a specific sector. Thus an industry is a subordinate of a specific economic sector category.

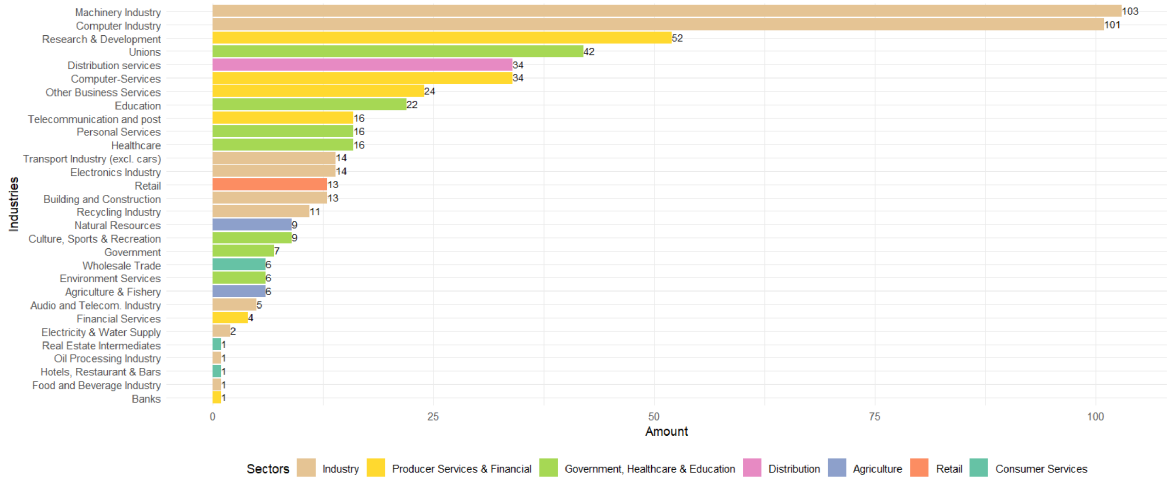

Figure 7 Publications in Industry 5.0 in Different Sector

Figure 7 depicting the distribution of Industry 5.0. research across industrial segments within a specific sector.The machinery industry leads with 103 publications, signifying the highest concentration of Industry 5.0. research. The significant presence of the Computer Industry and Research and Development suggests their crucial role in the potential application within Industry 5.0. Conversely, lower numbers in Telecommunications, Education, and Personal Services sectors imply a moderate influence of Industry 5.0. Furthermore, industries with zero publications indicated undeveloped exposure to Industry 5.0 literature.

3.3.1. Industrial Sector

Table 3 illustrates the subordinate segments of industrial sectors. The prevailing concepts in this industry revolve around Human-Machine collaboration [34], [35], [36], [37], [38], [39], progress towards the Cognitive Factory [35], [40], [41], [42], [43], and the adoption of new technologies [44], [45], [46], [47], [48], [49], [50], [51], [52]. While most publications focus on implementation, they largely remain in the experimental stage. Nonetheless, there are publications that delve into real-world implementations, particularly in areas such as finance, ICT development, and manufacturing.

Table 3. Publication Types in Industry Sector

Industries	Implementation	Concept	Literature Review	Total
Machinery Industry	50	35	18	**103**
Computer Industry	48	24	29	**101**
Electronics Industry	-	8	6	**14**
Transport Industry (excl. cars)	7	2	5	**14**
Building and Construction	4	7	2	**13**
Recycling Industry	-	7	4	**11**
Audio and Telecom. Industry	-	2	3	**5**
Electricity & Water Supply	2	-	-	**2**
Food and Beverage Industry	-	1	-	**1**
Oil Processing Industry	1	-	-	**1**
Tobacco Industry	0	-	-	**0**
Textile Industry	-	-	-	**0**
Clothing Industry	-	-	-	**0**
Leather Goods Industry	-	-	-	**0**

Timber Industry	-	-	-	**0**
Paper Industry	-	-	-	**0**
Publishing and Reproduction	-	-	-	**0**
Chemical Industry	-	-	-	**0**
Synthetic and Rubber Industry	-	-	-	**0**
Glass and Ceramic Industry	-	-	-	**0**
Primary Metal Industry	-	-	-	**0**
Metal Production Industry	-	-	-	**0**
Car Industry	-	-	-	**0**
Furniture Industry	-	-	-	**0**
Total	**112**	**86**	**67**	**265**

Existing technologies related to Industry 5.0. have not yet achieved significant concrete implementation breakthroughs specific to industry. Further technological development is necessary to realize Industry 5.0 [1], [53], [54], [55], [56], [57], [58], with only a few technologies capable of adapting to real-life situations. Only a handful of technologies have successfully been implemented in both experimental and real-world settings. However, most topics are only implemented as conceptual or theoretical ideas, lacking full-scale real-world application. Supported by other conceptual and literature review publications, these sectors are poised to emerge as the most influential in Industry 5.0. Consequently, the necessity for real-life implementation that meet the criteria of Industry 5.0 is undeniable. This can start with advancements in manufacturing robotics followed by worker collaboration with novel technologies such as Blockchain, AI, digital twin, etc.

3.4.2. Producer Services Sector

Producer services encompass a broad spectrum of specialized business activities that underpin the operation and expansion of various sectors within the economy [59]. Generally offered by professional firms or individuals, these services encompass a variety of functions including financial services, legal assistance, consulting, advertising, market research, logistics, and technological support [60] This explanation is directly proportional to [33] classification.

As shown in Table 4, there is a relatively even distribution in terms of the total amount of publications. However, there remains a notable lack of publications in the financial services and banking sectors. The predominant topics discussed include worker challenges in Industry 5.0 [61], [62], [63], [64], [65], industrial evolution or transition [66], [67], [68], big data & edge computing [54], [69], [70], [71], [72], and green technology [73], [74], [75]. In contrast, the financial sectors have few publications focusing on implementation and conceptual ideas, while the banking sector has only one conceptual idea publication. Authors are particularly intrigued by several topics, notably green technology and worker challenges. Green technology revolves around sustainable environmental technology, serving as supportive tools to streamline daily tasks. This topic shows promise as it emphasizes sustainable processes and minimizes waste at each technological step. Moving forward, worker challenges are a prevalent focus, with publications often discussing integration between humans and robots. However, there is limited discussion on human capabilities to collaborate with robots, especially in non-technological areas like finance. Even in computer services, there is contemplation about the implications of Industry 5.0's success on human roles. These implications remain largely undiscovered, as indicated by the limited publications on these two topics, suggesting prospects for future research.

Table 4. Publication Types in Producer Services Sector

Industries	Implementation	Concept	Literature Review	Total
Research & Development	5	18	29	**52**
Computer-Services	12	20	2	**34**
Other Business Services	15	7	2	**24**
Telecommunication and post	14	2	-	**16**
Financial Services	1	2	1	**4**
Banks	-	1	-	**1**
Total	**47**	**50**	**34**	**131**

3.4.3. Government Sector

Table 5 illustrates the influence of Industry 5.0 on the government, healthcare, and education sectors, encompassing unions/labor, personal services, culture, sports, recreation, healthcare, education, and environmental services. Notably, unions and education have more publications on concepts and literature reviews than on implementation, while healthcare and personal services focus more on implementation. In unions/labor, the conceptual framework is well-established, indicating that union principles are firmly in place [76], [77], [78]. Industry 5.0 has renewed efforts to realize labor and union ideals. Similarly, education aligns with Industry 5.0 values but lacks thorough exploration in implementation [79], [80], [81]. Conversely, healthcare and personal services are effectively embracing Industry 5.0, though with fewer publications, highlighting the need for deeper exploration of concepts and literature [82], [83], [84], [85]. Future research should focus on bridging the gap between established concepts and practical applications to advance implementation.

Table 5. Publication Types in Government, Healthcare & Education Sector

Industries	Implementation	Concept	Literature Review	Total
Unions	6	17	19	**42**
Education	7	13	2	**22**
Healthcare	11	3	2	**16**
Personal Services	13	1	2	**16**
Culture, Sports & Recreation	1	7	1	**9**
Government	3	3	1	**7**
Environment Services	3	2	1	**6**
Total	**44**	**46**	**28**	**118**

3.4.4. Distribution Sector

The term distribution sector encompasses the diverse industries and channels responsible for delivering products from manufacturers to end consumers. This includes wholesalers, retailers, and e-commerce platforms, along with the transportation and logistics companies involved in the movement of goods [86]. Table 6 shows that most of the discussions centered around general supply chain management. It was exploring the implementation of a human-centric approach throughout various stages of supply chain management, including warehouse management, logistics, tracking, and more [87], [88], [89], [90]. Additionally, there was discussion about the utilization of AI to streamline the distribution process, from assisting humans to tracking systems [91], [92], [93]. Despite publications focusing on specific cases, authors still regard them as part of distribution services since they address distribution as a whole rather than individual cases. This highlights the importance for future research to investigate each distribution method specifically, ensuring the even distribution of Industry 5.0 values across all industries.

Table 6 Publication Types in Distributor Sector

Industries	Implementation	Concept	Literature Review	Total
Distribution services	17	11	6	**34**
Distribution over land	-	-	-	**0**
Distribution over water	-	-	-	**0**
Distribution by air	-	-	-	**0**
Total	**17**	**11**	**6**	**34**

3.4.5. Agriculture Sector

Table 8 reveals a paucity of publications in the agriculture sector. Each publication type contains not more than 5 publications, indicating a pressing need for further investigations in this field. Authors identified an intriguing term: Agri-Enterprises influenced by Industry 5.0 values in a Chinese agriculture case study [94]. This represents a promising initial exploration of Industry 5.0 in agriculture and cultivation. The prevailing focus in this sector remains on conceptualizing how the potential value of Industry 5.0 can be integrated into agriculture [94], [95], [96]. Discussions surrounding natural resources predominantly center on energy usage, encompassing electricity, mining, and related topics [47], [97]. These discussions primarily revolve around conceptual ideas and models illustrating how energy is utilized in Industry 5.0. Therefore, to maximize its potential,

the nascent agriculture sector can further develop by exploring the interplay between Industry 5.0 and the production, utilization, and maintenance of energy, agriculture, and fisheries values.

Table 7 Publication Types in Agriculture Sector

Industries	Implementation	Concept	Literature Review	Total
Natural Resources	3	1	5	**9**
Agriculture & Fishery	1	4	1	**6**
Total	**4**	**5**	**6**	**15**

3.4.6. Retail Sector

The retail sector occupies a unique position due to its vast scale of operations and the varied methods it employs to reach consumers. Based on findings in the retail sector, discussions on implementation and conceptual ideas revolve around AI and various intelligence models for numerous business processes [98], [99], [100], [101], [102], [103]. In the literature review, the focus is on the maturity level of the business or business process in Industry 5.0 [104], [105], [106]. Authors suggest a greater focus on the value that Industry 5.0 offers as an overarching paradigm which bring comprehensive value to all business processes in an integrated manner.

Table 8 Publication Types in Retail Sector

Industries	Implementation	Concept	Literature Review	Total
Retail	3	3	7	**13**
Total	**3**	**3**	**7**	**13**

3.4.7. Consumer Sector

Last but not least is Consumer Services (see Table 9). The prevailing notion here revolves around portraying the current state of the trade world in relation to Industry 5.0 [107], [108], [109]. Understanding how Industry 5.0 can be embraced by various sectors proves challenging. However, the authors perceive this as an opportunity to advocate for its proper integration. Initiating this exploration involves identifying the potential relationships, connections, or correlations between each industry and Industry 5.0. Beginning with a literature review for each industry is preferable as it lays the groundwork for future research possibilities.

Table 9 Publication Types in Consumer Services Sector

Industries	Implementation	Concept	Literature Review	Total
Wholesale Trade	-	5	1	**6**
Hotels, Restaurant & Bars	1	-	-	**1**
Real Estate Intermediates	-	-	1	**1**
Movable est. intermed	-	-	-	**0**
Total	**1**	**5**	**2**	**8**

In summary, agriculture and retail are often overlooked sectors when discussing Industry 5.0. This may be due to the nature of these industries. Agriculture has inherently embraced green practices, making sustainability a natural aspect of the sector, and therefore, it is less discussed in the context of Industry 5.0. Retail, on the other hand, focuses primarily on selling and does not typically align with the core concepts of Industry 5.0. However, the principles of Industry 5.0 could still be applied to enhance the retail sector.

3.5. VOSviewer Analysis

To gain additional insights, the authors used VOSviewer to analyze 584 literature items, uncovering hidden publication patterns and keyword relationships. In Figure 8, circles represent keyword frequency, with larger circles indicating higher frequency. The colors of the connections range from blue (indicating weaker relationships) to yellow (indicating stronger relationships), illustrating the strength of associations between keywords. The visualization highlights "Industry 5.0" as the most frequently used keyword, followed by "Internet of Things," "human-centric," "Artificial Intelligence," and "embedded systems." These keywords are central to the Industry 5.0 discourse, reflecting their significant role in current research.

The connections between keywords in the visualization reveal their co-occurrence in the literature, suggesting thematic relationships. The strong link between "Industry 5.0" and "Internet of Things" (IoT) underscores the critical role of IoT in enabling the connectivity and data exchange essential to Industry 5.0. IoT facilitates real-time data collection, monitoring, and analysis, which are crucial for optimizing industrial operations and smart manufacturing. Applications include predictive maintenance and supply chain optimization through real-time tracking. Similarly, the frequent co-occurrence of "Artificial Intelligence" (AI) with "Industry 5.0" highlights AI's importance in automating and optimizing industrial processes, thereby enhancing efficiency and decision-making. AI processes vast amounts of data from IoT devices to identify patterns, predict outcomes, and make decisions. In manufacturing, AI optimizes production schedules, improves quality control, and enhances robotics, while AI-driven analytics provide insights into process improvements and innovation opportunities.

The visualization also illustrates how these key themes are interconnected, indicating a comprehensive approach to Industry 5.0. For instance, integrating IoT and AI with human-centric design can lead to smart factories where automated systems support human workers, creating a synergistic environment that maximizes both productivity and well-being. Although sustainability is frequently discussed, the limited research on resilience suggests a promising area for exploration. Future research should investigate how Industry 5.0 can enhance both sustainability and resilience by developing technologies that not only reduce environmental impact but also bolster the robustness of industrial systems against unforeseen challenges.

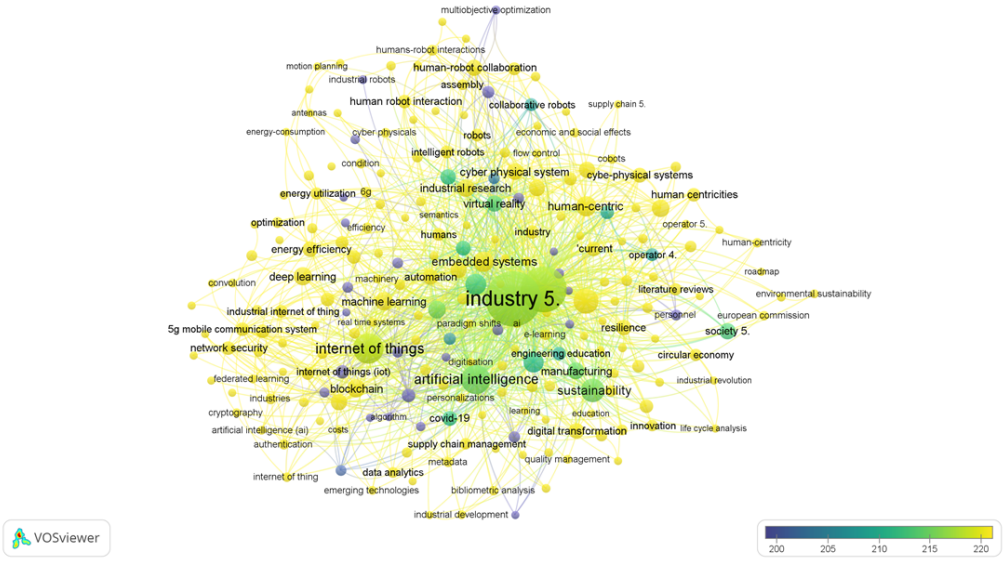

Figure 8. VOSviewer Keyword Analysis Result

In Figure 9 we can see the characteristic for each industry 5.0 pillars, which are sustainability, human-centricity, and resilience. Despite this, discussions on sustainability and resilience are limited. The sustainability circle focuses on the circular economy and life cycle analysis, with little resilience. Although the color for sustainability indicates a high keyword correlation, research on it is minimal. In Industry 5.0, sustainability should include sustainable energy use, waste reduction, and value chain creation. Resilience should cover both disruption resistance and adaptability. In conclusion, while technological advancements in Industry 5.0 are vital, sustainability, resilience, and a human-centric approach must not be overlooked. Future research should address these areas to provide a holistic understanding of Industry 5.0, ensuring technological progress does not compromise planetary and human well-being.

Fig. 9 The pillar of Industry 5.0 value on,
(a) Sustainability; (b) Resilience; (c) Human-centric.

Information Systems (IS) are comprehensive and integrated means for producing, storing, delivering, and processing information [110]. It's a complex structure that plays a pivotal role in the management and operation of modern organizations [111]. This section aims to delve deeper into this concept, particularly focusing on how IS can adapt and thrive in the context of Industry 5.0, a revolutionary phase in industrial development characterized by smart systems and automation.

To provide a structured and detailed exploration, the authors have decided to divide the future of IS in each industry into two core realms: conceptual value and implementation. The realm of conceptual value is essentially an intellectual construct. It will be depicted as a way of thinking and an idea of what the IS might look like in the era of Industry 5.0. This involves envisioning the theoretical aspects, potential features, and functionalities of IS in a highly automated and interconnected industrial environment. On the other hand, the realm of implementation is more practical and tangible. It will portray a realistic future prediction of how IS will be deployed and used in the era of Industry 5.0. This involves discussing the practical applications, potential challenges, and strategies for effectively integrating IS into various industrial processes.

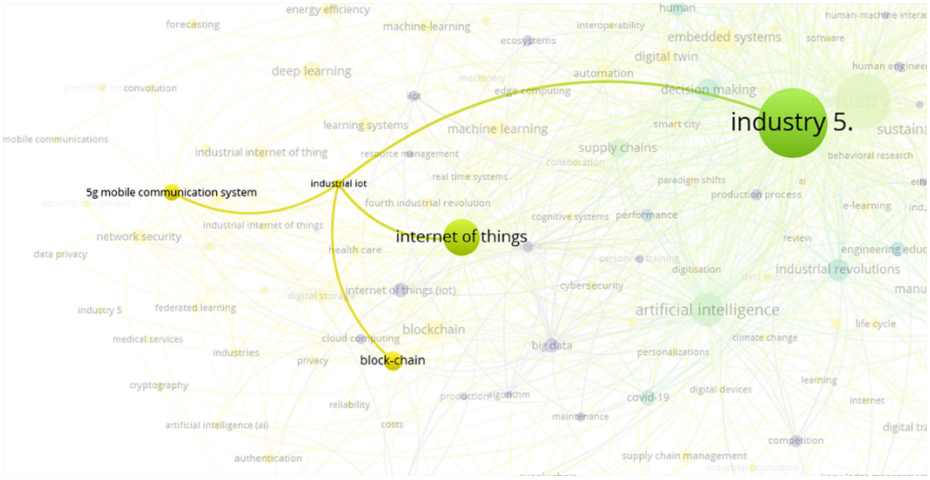

Fig. 10 Internet of Things (IoT) and Industry 5.0.

In the era of Industry 5.0, IS are expected to revolve around the evolving landscape of the Internet of Things (IoT) [112], [113]. It is evident that Industrial IoT will serve as a bridge connecting IoT to Industry 5.0. It also shown in figure 10 the relation within industry 5.0 with IoT trough industrial IoT. Furthermore, the demand for efficient information flow is evident in the advancements of 5G mobile communication systems and the intrinsic value of blockchain technology [114] (shown in figure 10). This implies that IS must adapt to meet the requirements of these two pivotal features: fast and accurate information flow and human centric IS. This adaptation aligns with the specific needs of various industrial sectors; in industrial manufacturing, there is a critical need for information to flow swiftly and accurately. This necessity is also paramount in the Distribution and Retail Sectors. From a conceptual perspective, IS must adopt a more human-centric approach. This means that systems should not only be fast and precise but also aligned with organizational needs, ensuring they are intuitive and user-friendly for individuals at every level of the industry.

From a practical standpoint, it is essential to prepare for and research new technologies thoroughly. Industries such as Manufacturing, Distribution, and Retail require secure and transparent methods for information delivery. In this context, the concept of Blockchain technology emerges as a viable solution. As illustrated in Figure 9, Blockchain is paving the way for innovative breakthroughs. The fundamental principle of Blockchain is that it operates on a "no single entity storage" model. It is a decentralized, distributed ledger that meticulously records the ownership of digital assets. The immutability of any data stored within the Blockchain ensures that it cannot be altered post-entry, positioning it as a formidable disruptor across various industries, including payments, cybersecurity, and healthcare. IS must begin to explore this domain actively, transitioning from theoretical research to practical implementation. For example, [115], [116] demonstrate how financial and information system sectors are conceptually embracing the intrinsic value of Blockchain to enhance their operations. These studies underscore the transformative potential of Blockchain when integrated into existing systems, highlighting its capacity to streamline processes, fortify security measures, and foster a new era of digital trust and efficiency.

To effectively integrate Industry 5.0 principles, it is crucial for various sectors to adapt their IS to meet the demands for fast, accurate information flow and a human-centric approach. These are few sectors and industries, they are highlighted because they are either significantly influenced by Industry 5.0 or remain largely unaffected by it.

Manufacturing is at the forefront of this evolution, requiring IS that can handle the rapid transmission of data and integrate seamlessly with advanced IoT and 5G technologies. The challenge here lies in ensuring that these systems are not only fast and precise but also tailored to the specific needs of manufacturing processes, which involve complex, high-volume data management. Solutions include developing adaptive systems that can manage real-time data processing and provide actionable insights to enhance operational efficiency.

Distribution and Retail sectors also face significant demands for efficient information flow. In these industries, the challenge is to implement IS that supports transparency and traceability, particularly in supply chain management. Blockchain technology offers a promising solution by providing a secure, decentralized ledger for tracking and verifying transactions. This can help address issues such as fraud, counterfeiting, and inefficiencies in supply chain operations. Implementing blockchain requires sectors to invest in infrastructure that supports decentralized networks and to train personnel in managing these new technologies.

For agriculture, which has traditionally been less engaged with Industry 5.0, integrating these principles involves overcoming unique challenges related to the sector's diverse and often remote operational environments. Practical solutions include deploying IoT sensors for real-time monitoring of crop and soil conditions and utilizing blockchain for transparent traceability of agricultural products from farm to table. These technologies can enhance productivity and sustainability but require significant investment in infrastructure and training.

Retail faces the challenge of adopting a human-centric approach to technology. This involves designing systems that are intuitive and user-friendly, ensuring that they align with the needs of both employees and customers. Implementing advanced IS in retail might include incorporating AI-driven customer service tools and personalized marketing strategies while ensuring that these systems are accessible and supportive of human operators.

Based on the findings above, the overall results align with the objectives of this research. Gaining a deeper understanding of Industry 5.0 across various sectors will assist in the development of strategies, policies, or other relevant actions. With the discovery that agriculture and retail are sectors less engaged with Industry 5.0, further research in these areas and preparation for the transition to Industry 5.0 can be pursued. Additionally, with the identification of certain information systems technologies that will become key pillars in the Industry 5.0 era, several preparatory steps can already be taken. Since Information Systems (IS) is a discipline utilized across all sectors, the insights provided by this research should help in preparing for what lies ahead.

4. CONCLUSION

This study employs a scoping review methodology, selected for its comprehensive data extraction capabilities, which provides an extensive overview of existing research on Industry 5.0. Unlike traditional systematic reviews, a scoping review maps out literature without assessing its quality. This approach identifies key concepts, evidence sources, and research gaps across a broad field, accommodating diverse study designs and evidence types to ensure a holistic view of the research landscape.

Given that Industry 5.0 is still in its nascent stages, this methodology is particularly suitable. It allows for a thorough examination of literature's evolution since its initial implicit references in 2016, with explicit discussions gaining traction by 2019. The study's framework, depicted in Figure 2, includes three critical phases: data findings, analysis, and conclusions. Phase 1 involved rigorous selection and categorization of articles, utilizing tools like Scopus and Mendeley for data management and verification. Phase 2 focused on detailed characterization and mapping using software such as Excel and VOSviewer, revealing publication trends and thematic distributions. Phase 3 synthesized these findings to highlight key insights and propose future research directions.

Results from the scoping review indicate a growing interest in Industry 5.0, as evidenced by increasing publication numbers across articles, conference papers, and reviews from 2018 to 2022. Sector-level analyses (illustrated in Figures 6 and 7) pay significant attention to sectors such as Industry and Producer Services, while highlighting gaps in areas like Agriculture and Retail. These findings underscore the need for further exploration, especially in implementing Industry 5.0 principles across diverse sectors.

The analysis using VOSviewer provided key insights into the discourse surrounding Industry 5.0, particularly its pillars: sustainability, resilience, and human-centric design. While discussions on sustainability, including the circular economy and lifecycle analysis, were well-represented, resilience was notably underexplored. This presents an opportunity for future research to investigate how Industry 5.0 can integrate technologies to enhance both environmental sustainability and operational resilience.

Future research and industry practice should focus on several key areas to bolster resilience within Industry 5.0 frameworks. First, it is crucial to enhance our understanding of resilience by exploring how Industry 5.0 technologies—such as AI and IoT—can be optimized to withstand technological failures, supply chain disruptions, and other operational risks. Developing specific resilience metrics and models tailored to Industry 5.0 applications will be essential. Additionally, addressing gaps in underrepresented sectors like Agriculture and Retail is important. Targeted research should explore how Industry 5.0 principles can be applied to these fields, considering their unique challenges and developing strategies for technology integration. Creating and testing frameworks to guide the integration of resilience practices into Industry 5.0 systems is also vital. These frameworks should offer actionable guidelines for organizations to strengthen their resilience capabilities and adapt to changing conditions. Detailed case studies on how different sectors—particularly those underrepresented in current research—have implemented Industry 5.0 principles to improve resilience will provide valuable insights and highlight successful strategies. Lastly, harmonizing resilience strategies with human-centric design principles is crucial. Research should focus on designing systems that support human operators during crises, enhance decision-making, and improve overall response capabilities.

Overall, while Industry 5.0 offers promising advancements, prioritizing resilience, particularly in underrepresented sectors, alongside sustainability and human-centric approaches is essential. Addressing these gaps will ensure that technological progress contributes to both operational stability and long-term societal well-being.

Additionally, Information Systems (IS) play a critical role in supporting Industry 5.0's evolution, especially in facilitating efficient information flow and human-centric design. Central themes such as "Industry 5.0," "Internet of Things," "Artificial Intelligence," and "human-centric design" emerged prominently, highlighting their pivotal roles in shaping future industrial landscapes. The visualization illustrated strong thematic connections, particularly how IoT and AI are intertwined

to optimize operations through real-time data analytics and automation. Technologies like Blockchain were noted as promising tools to enhance transparency and security in industrial processes, though practical implementation remains a key challenge. Overall, while Industry 5.0 promises technological advancements and efficiencies, the need to prioritize sustainability, resilience, and human-centric approaches cannot be overstated. Future research should focus on bridging these gaps to ensure that technological progress aligns with long-term planetary and societal well-being.

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