

## Review

# From Supply Chain 4.0 to Supply Chain 5.0: Findings from a Systematic Literature Review and Research Directions

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**Abstract:** The main purpose of this paper is to present what the Industry 5.0 phenomenon means in the supply chain context. A systematic literature review method was used to get evidence from the current knowledge linked to this theme. The results have evidenced a strong gap related to Industry 5.0 approaches for the supply chain field. Forty-one (41) publications, including conference and journal papers, have been found in the literature. Nineteen (19) words, which were grouped in four (4) clusters, have been identified in the data analysis. This was the basis to form the four (4) constructs of Industry 5.0: Industry Strategy, Innovation and Technologies, Society and Sustainability, and Transition Issues. Then, an alignment with the supply chain context was proposed, being the basis for the incipient Supply Chain 5.0 framework and its research agenda. Industry 5.0 is still in an embryonic and ideal stage. The literature is scarce and many other concepts and discoveries are going to emerge. Although this literature review is based on few available sources, it provides insightful and novel concepts related to Industry 5.0 in the supply chain context. Moreover, it presents a clear set of constructs and a structured research agenda to encourage researchers in deploying further conceptual and empirical works linked to the subject herein explored. Organizations' leadership, policymakers, and other practitioners involved in supply chains, and mainly those currently working with Industry 4.0 initiatives, can benefit from this research by having clear guidance regarding the dimensions needed to structurally design and implement an Industry 5.0 strategy. This article adds valuable insights to researchers and practitioners, by approaching the newest and revolutionary concept of the Industry 5.0 phenomenon in the supply chain context, which is still an unexplored theme.

**Keywords:** Supply Chain 5.0; Supply Chain 4.0; Industry 5.0; Industry 4.0; literature review; research agenda



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## 1. Introduction

The Industry 4.0 phenomenon has fostered several discussions among both academics and practitioners. The theme of Industry 4.0 was initially introduced in 2011 at the Hannover Fair—Germany [1]. Nowadays, Industry 4.0 is being considered as one of the main topics of the World Economic Forum's agenda and many countries' government agendas [1–5]. Industry 4.0 strategy impacts directly on the global competitive market, being a true source of value creation [6,7].

In the wave of Industry 4.0, several discussions and developments have been deployed through different countries and industry sectors [8–11]. Additionally, many topics of research have been deployed to create a better understanding of how this revolutionary phenomenon relates to other knowledge areas. Among these are included the themes of product development [12], performance measurement [13], small and medium enterprises—SMEs—in Industry 4.0 [14], production planning and control [15], strategic management [16], organizational structure [17,18], servitization [19], sustainability [20,21], and lean manufacturing [22,23].

Especially in the supply chain context, few studies have been deployed to get evidence regarding the influence of Industry 4.0 and its disruptive technologies on the supply chains.

Research that stands out with regard to this specific subject has been communicated by [24–32]. Some of these authors denominate the relation between Industry 4.0 and supply chains as Supply Chain 4.0. In their studies, there is a certain consensus that Industry 4.0 in supply chains means much more than only technology adoption. It involves understanding the capabilities required (e.g., infrastructure, people skills, coordination) to effectively implement Industry 4.0's technologies as well as generate the impact of these technologies on supply chains' performance criteria (e.g., transparency, responsiveness, efficiency, flexibility) and strategic goals.

Although Industry 4.0 is still in an initial stage, some concerns have been raised by researchers and practitioners concerning the role of humans amid this new technological environment. Some researchers have recently approached the role of humans in the Industry 4.0 context (e.g., Refs. [33–38]). Specifically, for the context of supply chains and logistics, Ref. [39] have discussed this issue, taking into consideration the role of logistics operators amid the surge of Industry 4.0's technologies context. Hence, the still visionary idea of Industry 5.0 has emerged in contrast to the paradigm that robots will dominate the industry environment. For instance, Ref. [40] argue that the highly automated environment allowed by Industry 4.0 puts humans at risk of no longer playing a valuable role. According to these authors, there is a relevant consensus that the era of robotics and automation in previous industrial revolutions brought about paradigm shifts in the manufacturing industry worldwide. Yet, they reinforce that although Industry 5.0 has still to be materialized, the same will occur with this new revolution, mainly because the set of technologies established with the Industry 4.0 phenomenon has been implicated in new paradigms.

This new trend defends a conciliating perspective of human–robot collaborative work [41,42]. Ref. [43] argues that policymakers and CEOs are overestimating the power of disruptive technologies (e.g., artificial intelligence, internet of things—IoT), since they are not focusing on the real innovation and effective potential of those technologies when properly interacting with human skills. In parallel with the Industry 5.0 concept, an approach proposed by Japan called Society 5.0 has also attracted attention from the scientific and practical audience. The terminology Society 5.0, also known as Super Smart Society, has been initially presented in the Fifth Science and Technology Basic Plan, which has been elaborated by the Japanese Council of Science, Technology and Innovation in 2016 [41].

Some authors have tried to clarify the interplay between Industry 4.0, Industry 5.0 and Society 5.0. For instance, according to [44], while Industry 4.0 is more concerned with the application of disruptive technologies, Industry 5.0 is focused on allowing a Society 5.0, with a sustainable human-centered society, by the use of those technologies from Industry 4.0. These authors also emphasize that it is challenging to create a Society 5.0 by incorporating the disruptive technologies from Industry 4.0. For [45], a Society 5.0 goes beyond the boundaries of technological and organizational transformation of the industrial system. It involves considering social and human aspects to achieve a sustainable environment in this technological context. Ref. [46] point out that Society 5.0 uses advanced technologies and products to connect people and things, share knowledge and information, and then create new social and business chains and values in society. From the industry aspect, these authors state that a Society 5.0 environment frees humans from exhausting routine work by exploring the advantages of Industry 4.0's technologies. Society 5.0 also helps in overcoming social problems by eliminating several social constraints.

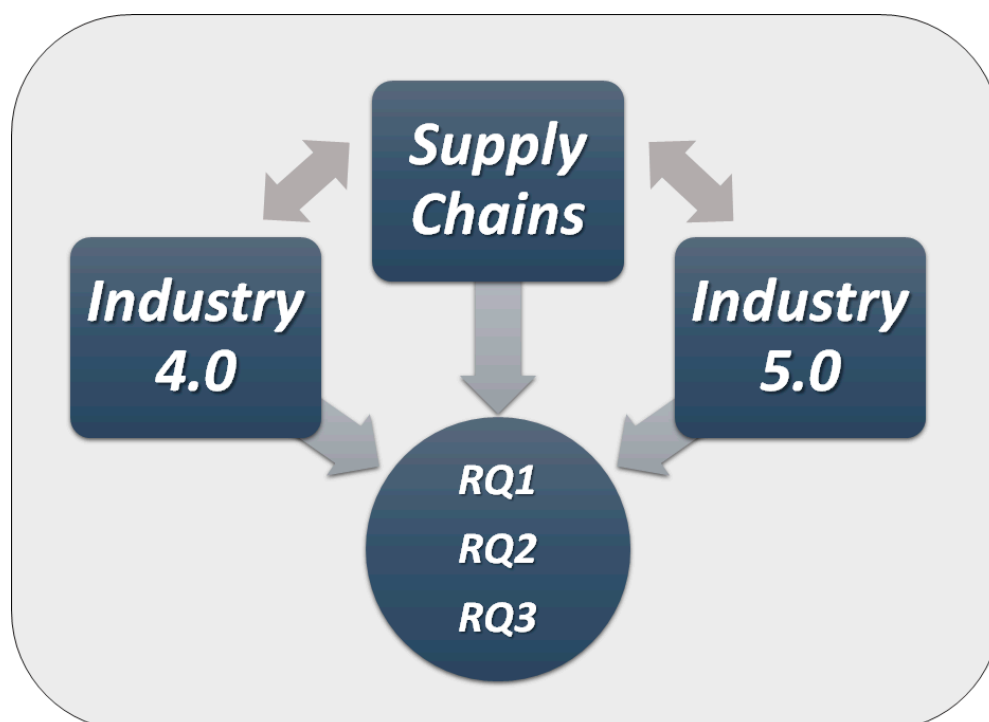
Ref. [47] emphasize that Industry 5.0 combines robots with human brains, which enhances the potential for developments quickly. Thus, the 'cobot' concept is one of the key elements of the upcoming industrial revolution. This concept of the cobot means working intelligently in the factory environment by the application of artificial intelligence, big data analytics, IoT, and other disruptive technologies, implying productivity improvement, wastes reduction, and the enhancement of sustainable goals. The main purpose of the Industry 5.0 idea is to foster the role of human beings in the manufacturing environment [47]. Moreover, some authors have affirmed that Industry 5.0 will allow personalized products

on a mass scale, adding high value to the customers [47–50]. Additionally, intelligent robots and systems will influence supply chains to an unprecedented level [51,52] point out that Supply Chain 5.0 is a trend which will involve three main perspectives: collaborative work between humans and robots (cobots), mass customization, and personalization to customers, and a super smart society (Society 5.0).

Although Industry 5.0 may still appear a premature and visionary idea, and the literature about it is scarce, this new revolutionary phenomenon is already being discussed by some of the organizations that are just now implementing Industry 4.0's programs. While Industry 4.0 creates the foundation for the smart factory, Industry 5.0 is the era of a social smart factory, because every single cooperative building block of a CPPS (cyber-physical production systems) will be able to develop communication with humans through the enterprise social networks. Actually, humans will be asked to collaborate with CPPS and complement the virtual and robotic elements of the automated production systems by the use of disruptive technologies, fostering faster and intuitive workflows [42].

Differently from the Industry 4.0 phenomenon, regarding Industry 5.0, there is a large gap related to what this fifth industrial revolution will mean to supply chains. In a search conducted in the Scopus and Web of Science databases, it was possible to identify that, although there are already papers approaching Industry 5.0 and Industry 4.0 relations, with regard to the supply chain subject the Industry 5.0 phenomenon is completely unexplored. Besides the lack of available knowledge regarding Industry 5.0 in the supply chain context, the gap relates to the fact that supply chains play a crucial role by providing services and products to society and the advancements of the Industry 5.0 phenomenon are going to certainly affect supply chain processes and members. Therefore, a proper understanding in respect to the relationship between Industry 5.0 and supply chains becomes paramount.

Therefore, this paper aims to present a novel perspective based on evidence obtained through the systematic literature review method. This new approach is herein called Supply Chain 5.0. Based on what has been contextualized in this Introduction section, this research aims to investigate the interplay between Industry 5.0, Industry 4.0, and Supply Chains as demonstrated in Figure 1. Figure 1 also links the research gap, as presented in this section, with the research questions' formulation.



**Figure 1.** Research scope.

Therefore, with the purpose to guide this research, three research questions were established as follows:

**RQ1**—What are the constructs which form the concept of Industry 5.0?

**RQ2**—How can Industry 5.0's constructs be aligned with the supply chain context?

**RQ3**—What are the main research questions related to Supply Chain 5.0, which should drive further research deployments?

Firstly, a systematic literature review focused on Industry 5.0 knowledge is conducted, to find any papers addressing the relationship between Industry 5.0 and supply chains. This aimed to understand the constructs related to this new phenomenon (**RQ1**). Then, an alignment between those constructs and the current knowledge about supply chains and Industry 4.0 interaction (i.e., Supply Chain 4.0) is proposed, with the purpose to provide a novel vision related to the relationship between Industry 5.0 and supply chains—SC 5.0 (**RQ2**). Based on this, some research questions are proposed to establish an initial research agenda regarding the relationship between Industry 5.0 and supply chains (**RQ3**).

This paper is structured as follows. This Introduction section contextualized and introduced the theme, motivation, and research gap of the present paper. The second section covers the systematic literature review method. The third section presents the findings gathered from the literature review. The fourth section presents the alignment between Supply Chain 4.0 and Supply Chain 5.0 as well as a research agenda with some research pathways related to Supply Chain 5.0. The fifth section ends this paper with conclusions containing theoretical and practical implications.

## 2. Systematic Literature Review

The systematic literature review is a robust method that effectively supports the exploration of unknown research issues. It is crucial to establish constructs and build theories that give support to empirical works [53]. According to [54], a systematic literature review can be divided into three steps: planning, conducting, and reporting. The planning phase refers to the establishment of search keywords, search databases, and search period. In the first phase, the search is undertaken, involving the screening of the first sample of articles. In this phase, inclusion and exclusion criteria are applied; the conduction of data analysis and elaboration of syntheses closes the phase. In the last step (reporting), results are structurally presented based on the relevant articles' sample analysis. With regard to results presentation, Ref. [55] suggest the matrix technique, which is an effective manner to properly make the transition from an author-centric to concept-centric approach. This research followed the three steps of [54] approach. Additionally, in the reporting phase, the technique suggested by [55] was used.

### 2.1. Planning the Literature Review

In the planning phase, two databases were chosen: Web of Science and Scopus. These are the most relevant search databases, covering the majority of scientific journals. In the sequence, keywords and their combination for the search were defined: "Industry 5.0", "Supply Chain", "Society 5.0" and "Industry 4.0". The chosen places for search in the articles were in the title and abstract and only journals and conference papers were considered. The period for the search of articles was from 2015 up to 2021. The year of 2015 was chosen as the start of the period because it was in this year when the Industry 5.0 theme has commenced to be discussed.

### 2.2. Conducting the Literature Review

In this step, the first sample of articles was identified. A total of 330 articles were first extracted from the databases. Then, the inclusion and exclusion criteria were applied by reading articles' abstracts. The exclusion criterion was articles out of the scope and duplicated articles. There were articles which only mentioned one of the keywords; however, they did not reflect the main approach aim for this research. The inclusion criterion was

articles that had as the main subject a combination of the keywords defined for the search (i.e., Industry 5.0, Supply Chain, Society 5.0, and Industry 4.0).

It is important to emphasize that it was not possible to identify articles addressing the relationship between Industry 5.0 and supply chains, confirming the gap which this research aims to cover. Then, after the screening of the sample of 330 articles, 41 articles were considered as relevant for the study herein considered, as demonstrated in Table 1. Figure 2 details the conduction of the systematic literature review process, considering the planned criteria.

**Table 1.** Forty-one relevant articles were extracted from the Web of Science and Scopus databases.

	<i>Authors</i>	<i>Source Title</i>	<i>Purpose</i>	<i>Database</i>
1	[56]	Journal of The Knowledge Economy	The purpose is to investigate the implementation of a smart environment for Industry 5.0 and Society 5.0. The case investigated is in the aviation industry sector.	Web of Science and Scopus
2	[43]	AI & Society	This paper discusses the aspect of human interaction with Industry 4.0's technologies and the trend towards Industry 5.0.	Web of Science
3	[44]	Sustainability	Its purpose is to study the use of OD (open data) in Industry 4.0, enabling a Society 5.0. They discovered that the bridge between Industry 4.0 and Society 5.0 is focused on technologies supporting the creation of a physical-to-digital-to-physical loop to ensure the sustainable development of a human-centered society.	Web of Science and Scopus
4	[57]	IPSI BGD Transactions on Internet Research	This research aimed to identify challenges and opportunities for implementing the concepts of Industry 4.0 and Society 5.0 in Russia, using a case study method.	Web of Science
5	[58]	IOP Conf. Series: Earth and Environmental Science	This paper brings a discussion regarding the benefits of Industry 4.0 and Society 5.0 for the real state and construction industries.	Scopus
6	[59]	Sustainability	This work refers to a survey carried out in Turkey, which investigates the relationship between Industry 4.0 and Society 5.0 in the context of Sustainable Development Goals—SDGs.	Scopus
7	[40]	Lecture Notes in Mechanical Engineering	This article is an investigation regarding human skills required for synchronization of robots in the Industry 5.0 environment.	Scopus
8	[60]	Lecture Notes in Mechanical Engineering	This research investigated the enablers for Industry 5.0 in the Indian manufacturing sector.	Scopus
9	[61]	Lecture Notes in Mechanical Engineering	This article presents the main conceptual differences between Industry 5.0 and Society 5.0.	Scopus
10	[62]	Journal of Industrial Integration and Management-Innovation and Entrepreneurship	This paper explores major technologies of Industry 5.0 which can be applied to the COVID-19 pandemic in the health sector.	Web of Science and Scopus
11	[63]	AATCC Review	This article presents the development of functional fiber computing for the textile industry in the context of Industry 5.0.	Web of Science and Scopus
12	[64]	Sustainability	This study examines how Industry 4.0 features and enabling technologies can support the transition to Society 5.0. It also investigates the roles of both open innovation and value co-creation within this transition.	Web of Science and Scopus



Table 1. Cont.

	<i>Authors</i>	<i>Source Title</i>	<i>Purpose</i>	<i>Database</i>
13	[41]	Journal of Knowledge Economy	This article presents a discussion regarding nuclear fusion energy through the lens of Industry 5.0 and Society 5.0.	Web of Science and Scopus
14	[47]	Journal of Industrial Integration and Management-Innovation and Entrepreneurship	This paper is a discussion about Industry 4.0 and Industry 5.0 and presents the main capabilities and elements needed to implement Industry 5.0 in the manufacturing industry.	Web of Science and Scopus
15	[42]	Applied Sciences-Basel	This paper covers the value-oriented and ethical technology engineering aspects of Industry 5.0, evidencing the findings through a survey of industry leaders from different companies.	Web of Science and Scopus
16	[46]	Kybernetes	This article discusses the relationship between Society 5.0, Industry 4.0, responsible economic development, and social problems solutions through the enhancement of corporate social responsibility (CSR) in organizations.	Web of Science and Scopus
17	[50]	Information	This research presents an innovation management framework—absolute innovation management (AIM)—as an innovation ecosystem for the Industry 5.0 context.	Web of Science and Scopus
18	[65]	International Review	This article provides a general view regarding actual development directions of the concepts of Industry 4.0 and Society 5.0, taking into consideration the context of sustainable development.	Web of Science
19	[66]	Intelligent Distributed Computing XIII	This article presents a conceptual model of an advanced digital platform for adaptive management of enterprises considering the context of Industry 5.0.	Web of Science and Scopus
20	[67]	Energy Conversion and Management: X	It considers aspects of the transition from Industry 4.0 to Industry 5.0 in the algae industry.	Scopus
21	[68]	Journal of Asian Finance, Economics and Business	The article is a discussion regarding cyberloafing effects through the lens of Industry 4.0 and Society 5.0.	Scopus
22	[69]	Journal of Physics: Conference Series	This work demonstrates a conceptual approach of a control system of multitasking between Society 5.0 and Industry 5.0.	Scopus
23	[70]	IOP Conference Series: Materials Science and Engineering	This paper presents the intelligent complex security management system for Industry 5.0 (FEC—fuel and energy complex), based on the Russian human–machine concept.	Scopus
24	[71]	IOP Conference Series: Materials Science and Engineering	This article provides an approach related to condition-based maintenance (CBM) and machine learning of artificial intelligence (MLAI) considering the context of Industry 4.0 and Society 5.0.	Scopus
25	[72]	AIP Conference Proceedings	This paper discusses the main technologies for the Industry 5.0 manufacturing systems design.	Scopus
26	[73]	Lecture Notes in Mechanical Engineering	This article proposes some areas that will need to be addressed with regard to the Industry 5.0 trend.	Scopus
27	[74]	CEUR Workshop Proceedings	The purpose of this study was to determine the level of readiness of municipalities in the Samara Oblast area to introduce Industry 5.0 technologies.	Scopus

Table 1. Cont.

	<i>Authors</i>	<i>Source Title</i>	<i>Purpose</i>	<i>Database</i>
28	[75]	European Journal of Molecular & Clinical Medicine	This article presents the main current technological developments of Industry 4.0 and future modifications for the Industry 5.0 context.	Scopus
29	[76]	Proceedings of the 5th North America International Conference on Industrial Engineering and Operations Management	This paper proposes a model of food product innovation for food manufacturing SMEs considering the trends of Industry 5.0 and Society 5.0.	Scopus
30	[51]	Sustainability	This paper introduces the concept of Industry 5.0 as well as presents key features and concerns related to Industry 5.0.	Web of Science and Scopus
31	[45]	International Scientific Conference Digital Transformation on Manufacturing, Infrastructure and Service	This paper presents the relationship between the objectives and goals of sustainable development and the concepts of Industry 4.0 and Society 5.0.	Web of Science and Scopus
32	[77]	4th Annual Applied Science and Engineering Conference	This research investigates the feasibilities and challenges of the implementation of fintech in small and medium industries in the Society 5.0 era.	Web of Science and Scopus
33	[78]	Next-Generation Spectroscopic Technologies XII	This paper explores the use of smartphone applications in Industry 4.0 or Society 5.0 applications.	Web of Science and Scopus
34	[79]	Proceedings of the 2019 IEEE International Conference of Quality Management, Transport and Information Security, Information Technologies	This article discusses the main technologies and approaches which will contribute to the transition from Industry 4.0 to Industry 5.0.	Scopus
35	[80]	Procedia Computer Science	This article presents a discussion related to Industry 5.0, especially linked to the human–robot co-working issues from an organizational and human relations perspective.	Scopus
36	[49]	International Journal of Recent Technology and Engineering	This study presents an innovative model to support the transition from Industry 4.0 to Industry 5.0.	Scopus
37	[81]	OMICS-A Journal of Integrative Biology	This paper presents a vision of Industry 5.0 based on big data, the internet of things, and artificial intelligence.	Web of Science and Scopus
38	[48]	Journal of Clinical Orthopedics and Trauma	This article discusses the main applications of Industry 5.0 and their benefits to the medical industry.	Scopus
39	[82]	Zigonghua Xuebao/Acta Automatica Sinica	This paper proposes a system architecture for the nuclear power industry considering the Industry 5.0 context.	Scopus
40	[83]	Engineering	This research investigates how Industry 5.0 may impact the development of bionics (synthetic biology)	Web of Science and Scopus
41	[84]	Zigonghua Xuebao/Acta Automatica Sinica	In this paper, a new framework called Energy 5.0 is proposed, taking into consideration interactions and trends of energy and industry development as well as other advances.	Scopus

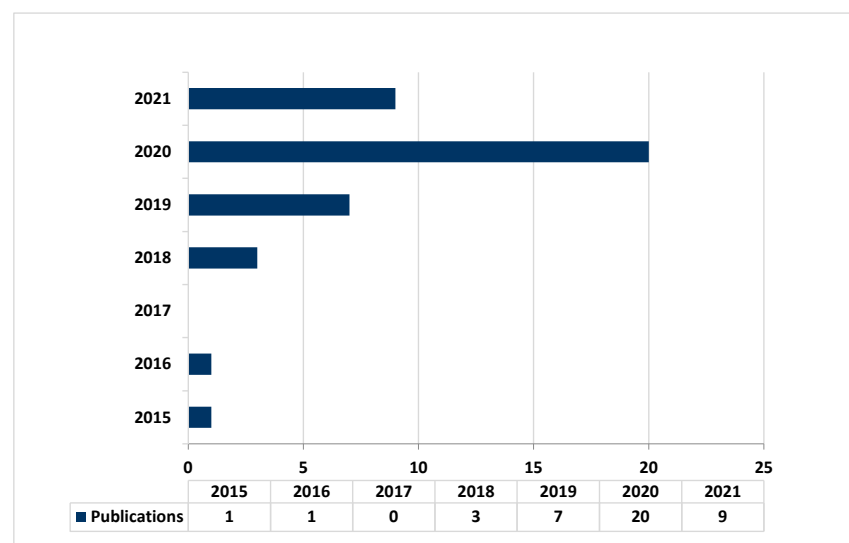


**Figure 2.** The systematic literature review process.

### 2.3. Reporting the Literature Review

After the conduction of the literature review, it was possible to analyze the forty-one (41) articles. Based on Table 1, it is possible to see how recent are publications related to Industry 5.0, the first publication being in 2015.

Figure 3 demonstrates the evolution of publications during the time since 2016. This shows why there are still few publications in the field. Considering that the year 2021 is still in the first quarter, the trend seems to be significantly high.



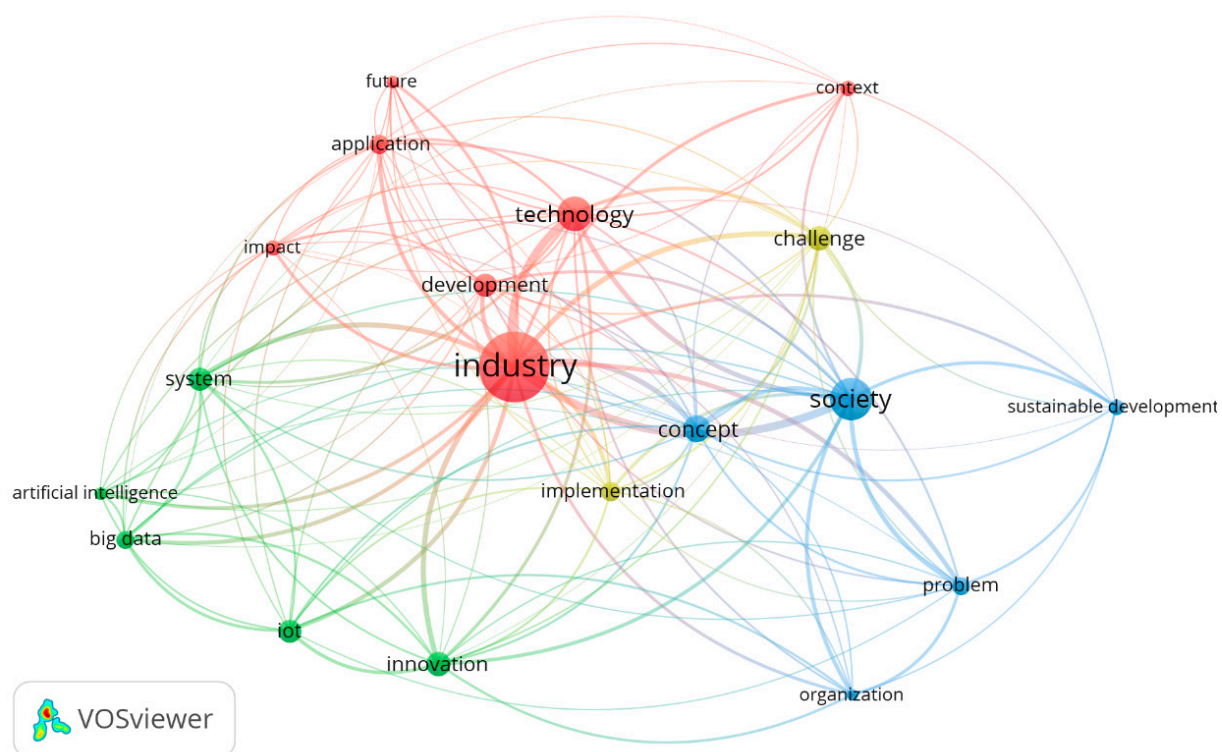
**Figure 3.** Quantity of publications since 2015 related to Industry 5.0.



Other evidence from Table 1 is regarding the journals where articles about Industry 5.0 have been published. The majority of publications are in journals on supply chain and operations management (which is the aim of this research), and in journals in the management field in general. This demonstrates how incipient the subject of Industry 5.0 is as well as the need for a broader discussion on this theme.

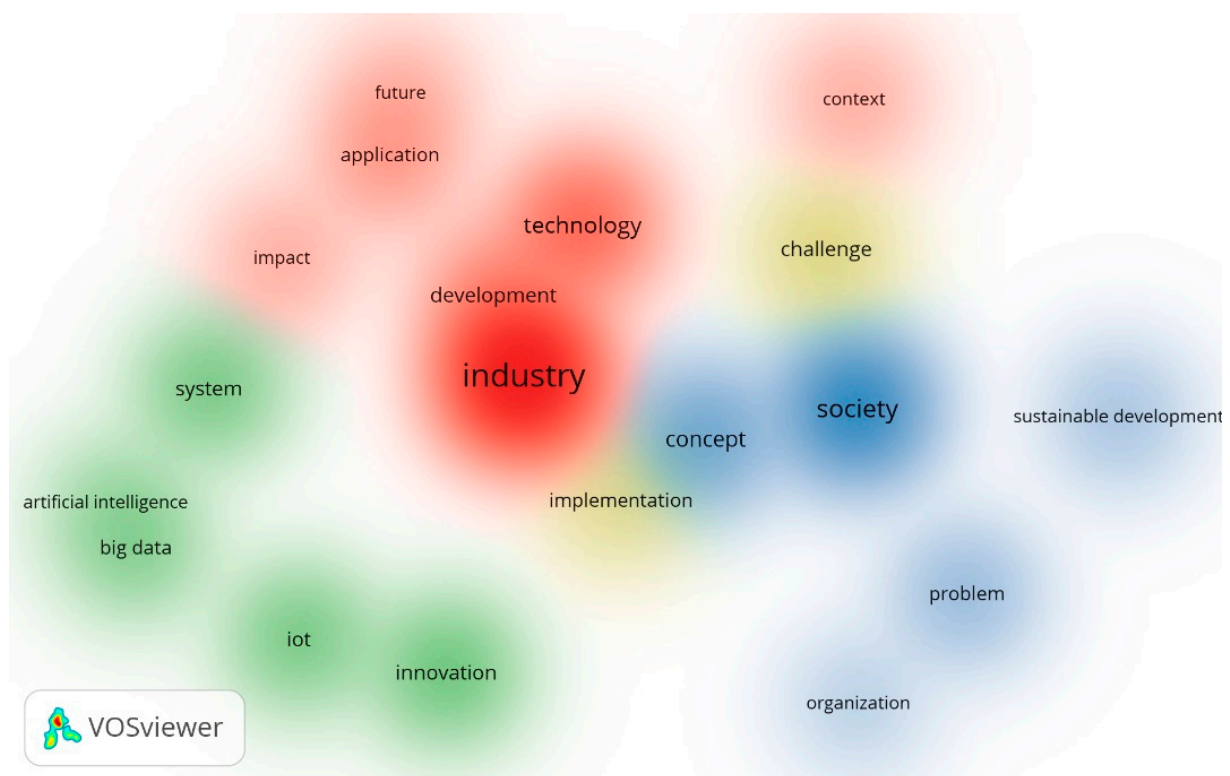
For the analysis of the articles sample, VOSviewer software was adopted. VOSviewer is an open software used to analyze literature content by providing a data network, indicators, and maps. This software was developed by [85] from Leiden University, and it has been largely used by researchers to support literature reviews.

With the aim to obtain reliable data from the VOSviewer software, the parameter of a minimum of five words co-occurring was set. Using this parameter, nineteen (19) words were identified as shown in Figure 4.



**Figure 4.** Graphic showing the links between keywords of articles sampled.

As can be noted in the density graphic (Figure 5) as well as in Table 2, four (4) clusters were formed. These clusters were the basis of the constructs that will be further presented in this article. They were formed based on Figure 5, which was generated by the VOSviewer software. These clusters were formed by the software based on the common relations between the words in the analyzed sample of articles. Another important piece of evidence is related to the words' links. A link represents a connection or a relation between two words. The link may be measured by a strength value. The higher this strength value, the stronger the link. The strength of a link may indicate the number of publications in which two terms occur together, in the case of co-occurring word links [86]. From Figure 4 and Table 2, we can see the links between the words which had more co-occurrences in the sample of forty-one (41) articles. Among these stand out industry, society, and technology. These were the words that have the highest weights regarding both occurrences and link strength. This makes sense, since these three words are core for the concept of Industry 5.0.



**Figure 5.** Density graphic of clustered words formed by VOSviewer from the articles sample.

**Table 2.** Main words clustered by VOSviewer software with regard to articles addressing the subjects of Industry 5.0, Society 5.0, and Industry 4.0.

Word	Cluster	Weight <Occurrences>	Weight <Links>	Weight <Total Link Strength>
Industry	1	74	18	955
Society	3	30	17	506
Technology	1	21	18	387
Concept	3	14	18	230
Innovation	2	12	15	227
Challenge	4	11	15	186
Development	1	10	15	141
IoT	2	10	13	164
System	2	10	16	167
Application	1	8	15	114
Implementation	4	8	14	137
Big data	2	7	12	132
Problem	3	7	13	184
Context	1	5	11	71
Impact	1	5	15	78
Sustainable Development	3	5	9	85
Artificial intelligence	2	4	12	79
Future	1	4	10	62
Organization	3	3	10	139

Regarding the cluster analysis, the evidence presented in Figure 5 as well as in Table 2 shows that cluster 1 was formed by articles that are related to issues concerning **Industry Strategy**. The seven (7) words in this cluster are: industry, technology, development, context, application, impact, and future. These are the words grouped in red color in Figure 5.

In respect to cluster 2, articles focused more on issues linked to **Innovation and Technologies**, and there were five (5) words clustered in that regard: innovation, IoT, system, big data, and artificial intelligence. These are the words grouped in green color in Figure 5. Cluster 3 was formed by five (5) words: society, concept, problem, sustainable development, and organization. As can be observed, articles from this cluster were concerned with **Society and Sustainability** issues. In Figure 5, this cluster is represented by the words grouped in blue color. Lastly, cluster 4 contains only two (2) words, challenge and implementation, which appear in articles addressing aspects of the **Transition Issues** arising from moving from Industry 4.0 to Industry 5.0. This cluster is formed by words grouped in yellow color in Figure 5. These results are supported by the author's concept-centric matrix (Table 3), as suggested by [55]. In that matrix, it is possible to verify from which of the forty-one (41) authors (articles) words and their formed clusters have originated. Using this literature review report, this article will consider the four (4) aforementioned evidenced elements as Industry 5.0's constructs: **Industry Strategy, Innovation and Technologies, Society and Sustainability, and Transition Issues**.

**Table 3.** Matrix-Industry 5.0's constructs and words versus authors.

	Industry Strategy (Cluster 1)							Innovation and Technologies (Cluster 2)					Social and Sustainability (Cluster 3)					Transition Issues (Cluster 4)	
Authors/Words	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
[56]	*	*		*	*	*	*	*	*				*		*	*	*	*	*
[43]	*	*	*		*	*	*	*	*	*	*	*			*	*	*	*	*
[44]								*	*	*	*	*		*	*	*	*	*	*
[57]	*		*		*		*						*		*	*	*	*	*
[58]	*	*			*		*						*	*					*
[59]	*	*	*		*	*			*	*	*	*	*	*	*	*		*	*
[40]	*	*	*		*		*		*	*	*	*						*	*
[60]	*	*	*	*	*	*	*									*	*	*	*
[61]	*	*			*								*	*			*		
[62]	*	*		*	*	*		*	*	*	*	*			*			*	*
[63]	*	*	*	*	*				*	*	*	*							*
[64]								*	*	*	*		*	*	*	*	*	*	*
[41]	*	*	*		*	*	*						*		*	*	*	*	*
[47]	*	*	*	*	*	*	*	*	*	*	*	*				*			
[42]	*	*			*	*	*		*	*	*	*	*			*	*	*	*
[46]	*	*	*		*			*	*	*	*	*	*	*	*	*	*	*	*
[50]	*	*	*		*		*	*	*	*	*	*	*		*	*	*	*	*
[65]													*	*	*	*	*	*	*
[66]	*	*						*		*	*			*		*	*	*	*
[67]	*	*				*	*	*				*				*			
[68]	*								*			*					*		*
[69]	*	*			*	*	*		*	*	*	*	*	*					
[70]	*	*		*	*		*			*	*	*							*
[71]	*	*			*				*	*	*	*							
[72]	*	*		*	*	*	*		*	*	*	*						*	*
[73]	*	*	*		*	*	*						*				*	*	*
[74]	*	*	*	*	*		*		*	*	*	*						*	*
[75]	*	*	*		*			*	*	*	*	*	*			*		*	*
[76]	*	*	*		*		*	*	*	*	*	*				*		*	*
[51]	*	*	*	*	*	*	*		*	*	*	*						*	*
[45]	*	*	*		*			*			*		*	*	*	*		*	*
[77]									*				*				*	*	*
[78]	*	*		*	*				*	*	*		*					*	*
[79]	*	*			*	*	*	*				*	*		*	*	*	*	*
[80]	*	*	*	*	*	*	*		*	*	*	*	*		*	*	*	*	*
[49]	*	*			*	*	*	*				*	*	*		*	*	*	*
[81]	*	*	*	*	*		*	*	*	*	*	*	*	*				*	*
[48]	*	*	*	*	*	*	*	*	*	*	*	*						*	*
[82]	*	*	*		*		*	*	*	*		*	*			*			*
[83]	*	*	*	*	*	*	*	*	*	*		*	*						*
[84]	*	*	*		*		*	*	*	*	*	*	*		*				*

1—industry, 2—technology, 3—development, 4—application, 5—context, 6—impact, 7—future, 8—innovation, 9—IoT, 10—system, 11—big data, 12—artificial intelligence, 13—society, 14—concept, 15—problem, 16—sustainable development, 17—organization, 18—challenge, 19—implementation.

### 3. Industry 5.0's Constructs and the Supply Chain Context

#### 3.1. Discussion about the Constructs for Industry 5.0

In Section 2.3, the four (4) identified constructs of Industry 5.0 from the analysis of the literature review were presented. This section will present the concept for each one of these constructs and their related words as demonstrated in Table 3. The answer to RQ1 is the aim of this section.

##### 3.1.1. Construct 1—Industry Strategy

As aforementioned, this construct was formed by seven (7) keywords: industry, technology, development, context, application, impact, and future. It is related to the Industry 5.0 strategy because articles have approached Industry 5.0 as a whole including this futuristic context, considering the possibilities of technologies' applications and their impacts on the future. This construct is related to the other constructs once the technologies' applications are deployed in Construct 2—*Innovation and Technologies*, which with the development of Industry 5.0's strategy, directly impacts Construct 3—*Society and Sustainability*. However, the Industry 5.0 strategy faces challenges and implementation issues, mainly regarding the change from Industry 4.0's paradigms. This is linked to Construct 4—*Transition Issues*.

For [48], Industry 5.0 allows increasing collaboration between humans and smart systems through advanced industrial automation, with the support of critical thinking skills. Ref. [72] affirm that Industry 5.0 is related to the efficient utilization of the workforce formed by machines and people in the manufacturing environment. This concept will redefine the manner in which skilled people are treated in the manufacturing scenario. According to [73], there is a relevant consensus that the era of robotics and automation in previous industrial revolutions brought about paradigm shifts in the manufacturing industry worldwide. For these authors, although Industry 5.0 has still to be materialized, the same will occur with this new revolution, mainly because the set of technologies established with the Industry 4.0 phenomenon is implicated in new paradigms.

In respect to Industry 5.0, some authors have emphasized the impact on personalization. According to [49], customer experience and organizational agility are sources of competitive advantage for Industry 5.0. For these authors, personalization and society collaboration, enabled by Industry 4.0 technologies, are key elements of Industry 5.0. Ref. [60] affirm that although there is a strong trend in highly focused technology applications, modern challenges of customization, personalization, and technology upgrading are only possible with human involvement. These modern challenges have led to Industry 5.0, which aims to align technology advancement with human empowerment. According to [75], some futurists have initiated discussion of Industry 5.0, considering this as the theme of adding a human touch or personalization through collaboration and co-working between humans and robots. Industry 5.0 aims to provide more customized products and services to the customer, characterized by the era of personalization [50]. Ref. [65] point out that the focus of Industry 5.0 is to get efficient use of machines and humans at the same time, creating a synergistic environment and allowing personalization to achieve a higher level in the Industry 5.0 context. For instance, in the medical industry, Ref. [48] affirm that Industry 5.0 provides the opportunity of mass personalization, being able to produce several types of implants according to the patient's requirements.

##### 3.1.2. Construct 2—Innovation and Technologies

This second construct was formed by seven (5) keywords: innovation, IoT, system, big data, and artificial intelligence. Authors have mostly mentioned these technologies as the scaffolding for creating an Industry 5.0 environment, although they belong to the current age of Industry 4.0. Industry 4.0's technologies are seen as the basis for implementing the Industry 5.0 approach [64]. However, some authors have mentioned new technology approaches integrated with those already applied in Industry 4.0 are required, and innovation plays a crucial role in this process.

For instance, Ref. [47] have identified seventeen (17) components of Industry 5.0. They are big data, collaborative robots (cobots), smart sensors, internet of things, artificial intelligence, multi-agent systems and technologies, digital ecosystems, digital manufacturing, complex adaptative systems, smart materials, 3D printing, 4D printing, 5D printing, 3D scanning, holography, and virtual reality. Ref. [42] argue that technologies that enhance cognitive capabilities do not only include those linked to artificial intelligence (e.g., cognitive computing, computer vision, knowledge representation, machine learning, recommendation systems and planning, scheduling, and optimization algorithms) but also include simulation for what-if scenario analysis, big data analytics, cloud computing, and virtual reality. Ref. [50] state that Industry 5.0 is characterized by a digital smart society, the integration of virtual and physical spaces, internet of things, robots, augmented reality, innovation ecosystem, brain-machine interface, and human centrality of technology. With regard to innovation, Ref. [50] emphasize that as Industry 5.0 is gaining relevance, the focus of innovation management becomes paramount. In that sense, Ref. [56] affirm that several scholars have emphasized the importance and role of modifying the innovation management framework with a focus on human/user-centeredness. Ref. [48] consider that the main components of Industry 5.0 are collaborative robots, internet of everything, multi-agent systems and technologies, complex adaptative systems, smart manufacturing, digital ecosystems, and emergent artificial intelligence. Ref. [79] affirm that there is a set of technologies and approaches which will give a format for Industry 5.0, such as distributed computers and distributed robotics, internet of things, multi-agent systems and technologies, complex adaptative systems, emergent intelligence, energetics, and new enterprise architecture. For the implementation of Industry 5.0, some advanced technologies are required when compared with those traditional to Industry 4.0. Some of them are networked sensor data interoperability, digital twins, shopfloor trackers, virtual training, intelligent autonomous systems, and advances in sensing technologies and machine cognition [51].

### 3.1.3. Construct 3—Society and Sustainability

Society and Sustainability construct was formed by five (5) keywords: society, concept, problem, sustainable development, and organization. Some authors have considered social and sustainable aspects as the main elements impacted by the implementation of the Industry 5.0 approach.

According to [64], Industry 4.0's technologies play a crucial role in the search for a Society 5.0. This is a society with sustainability at its core, supported by disruptive technologies. Particularly, information and data play an essential role in the achievement of Society 5.0's purpose. Ref. [45] consider that a Society 5.0 goes beyond the boundaries of technological and organizational transformation of the industrial system. It involves considering social and human aspects with the aim to achieve a sustainable environment in this technological context.

For [80], Industry 5.0 includes two visions: one is related to the interaction between humans and robots and the other is approaching issues related to the bioeconomy, which is pretty much related to the sustainability issues. For instance, Ref. [67] emphasize that Industry 5.0 may generate huge and positive impacts in terms of sustainability in production systems (e.g., algae production). Yet, Ref. [59] affirm that Society 5.0 becomes an obligatory practice to get stability in terms of sustainable economic due to the advent of Industry 4.0. The main idea of the concepts of Industry 5.0 and Society 5.0 is developing from digital manufacturing to digital society. Social orientation and technical innovations from Industry 4.0 were the basis for the concept of Industry 5.0, being focused on more sustainable development. Industry 5.0 and Society 5.0 have as their main aim digital technologies for the development of society [65].

### 3.1.4. Construct 4—Transition Issues

For this fourth construct, only two words were grouped: challenge and implementation. It is related to the challenges and implementation aspects that must be addressed



for Industry 5.0 to become a reality. The transition from a fully technological to a balanced human-centric perspective is being considered as one of the main challenges and the Industry 4.0 paradigm to be overcome.

In that sense, Ref. [44] emphasize that it is challenging to create an Industry 5.0 by incorporating the disruptive technologies from Industry 4.0. Ref. [80] state that although there are few visions about what Industry 5.0 means, some futurists are fostering this theme. One emerging theme is human–robot co-working and its implications from the organizational and human relations side. According to these authors, psychological, social, ethical, learning, legal, and regulatory issues will play some of the most important roles to properly guide and regulate the relations between humans and robots. In the same sense, Ref. [73] emphasize that some areas need to be addressed with regard to Industry 5.0 implementation, including education and skills, working environment, the relationship between productivity and wages, technologies and human redundancies, optimum products, sustainability, governance, and ethics. Ref. [56] argue that the implementation of strategies for Industry 5.0 often depends on a series of factors for which sharing is necessary, such as any territorial support in growth policies. Institutions, entrepreneurs, and managers should take into consideration these differences and plan interventions reflecting the real conditions of their contexts. Ref. [40] propose to consider four main elements in designing Industry 5.0's strategy: organization, people, technology, and tasks. Ref. [73] emphasize that some areas that need to be addressed with regard to Industry 5.0 trend are education and skills, working environment, the relationship between productivity and wages, technologies versus human redundancies, optimum products, sustainability, governance, and ethics.

### 3.2. Alignment with the Supply Chain Context

In the current context, Supply Chain 4.0 has been reasonably discussed by the academic and practical audience. Some researchers have proposed some frameworks for the development of a Supply Chain 4.0 strategy. Among these stand out the models proposed by [24–31]. In their majority, these proposals consider similar aspects which have been extracted from the literature review about Industry 5.0 herein presented and discussed in Section 3.1. Supply Chain 4.0 also takes into consideration aspects such as its own strategy, a set of disruptive technologies, required capabilities and other criteria such as challenges to properly implement these disruptive technologies, and implications in terms of the performance of the supply chain processes.

In order to follow the structured rationale of this article, the alignment between Supply Chain 5.0 and Supply Chain 4.0 will be presented according to the four (4) constructs extracted from the systematic literature review, as presented and discussed in Section 3.1.

Concerning the construct **Industry Strategy**, while the literature considers the Supply Chain 4.0 concept as having a highly technological environment focus, Supply Chain 5.0 keeps this technological aspect, but also considers a balanced human–technological environment, mainly allowed by cobots (collaborative robots). Supply Chain 4.0 also aims to have a mass customization advantage besides enabling greater performance from the supply chain's processes in terms of transparency, responsiveness, flexibility, waste reductions, and efficiency. Supply Chain 5.0 seeks to keep those performance improvements, but also add more value by pursuing a mass personalization of products and services.

In respect to the construct **Innovation and Technologies**, Supply Chain 4.0 is formed by technologies such as IoT, big data analytics, 3D printing, cloud computing, robotics, blockchain, augmented reality, and artificial intelligence. These technologies remain in Supply Chain 5.0, and artificial intelligence is enhanced. Indeed, these Industry 4.0 technologies are the scaffolding for the implementation of Supply Chain 5.0; however, new technological advancements are added as well, including collaborative robots (cobots), multi-agent systems and technologies, digital ecosystems, complex adaptive systems, 4D printing, 5D printing, 3D scanning, holography, intelligent autonomous systems, evergetics,



and machine cognition. Additionally, the approach of innovation ecosystems is going to play a crucial role in this upcoming technological transformation.

In the construct of **Society and Sustainability**, while in Supply Chain 4.0 the society is more passive, being smoothly impacted by Industry 4.0's technologies, in the Supply Chain 5.0 approach society is an active and target element. In this new industrial revolution, one of the main aims is to create a super and digital smart society. In this new concept, the focus goes beyond the organization's thresholds and embraces the supply chain's linked society. Additionally, in Supply Chain 5.0, sustainable development becomes one of the main targets, much more than only being impacted by technologies, as it is being approached in the current context of Supply Chain 4.0. This interaction between Supply Chain 5.0's technologies and approach and smart society must be designed to create a most advanced sustainable environment in both organizations and societies.

Regarding the **Transition Issues** construct, authors who have discussed Supply Chain 4.0 have in general considered as challenges and implementation issues aspects such as coordination and leadership support, digital infrastructure, strategic alignment, and people skills and training. In the Supply Chain 5.0 concept these issues remain; however, they become more complex and comprehensive, by including aspects such as psychological issues, workers' safety, social, ethical, learning, and legal and regulatory issues. Lastly, the main challenge is the paradigm transition which involves a change from a fully technological to a balanced human-centric perspective.

Based on the presented alignment, Figure 6 shows the framework with a vision of the Supply Chain 5.0 concept and structure.

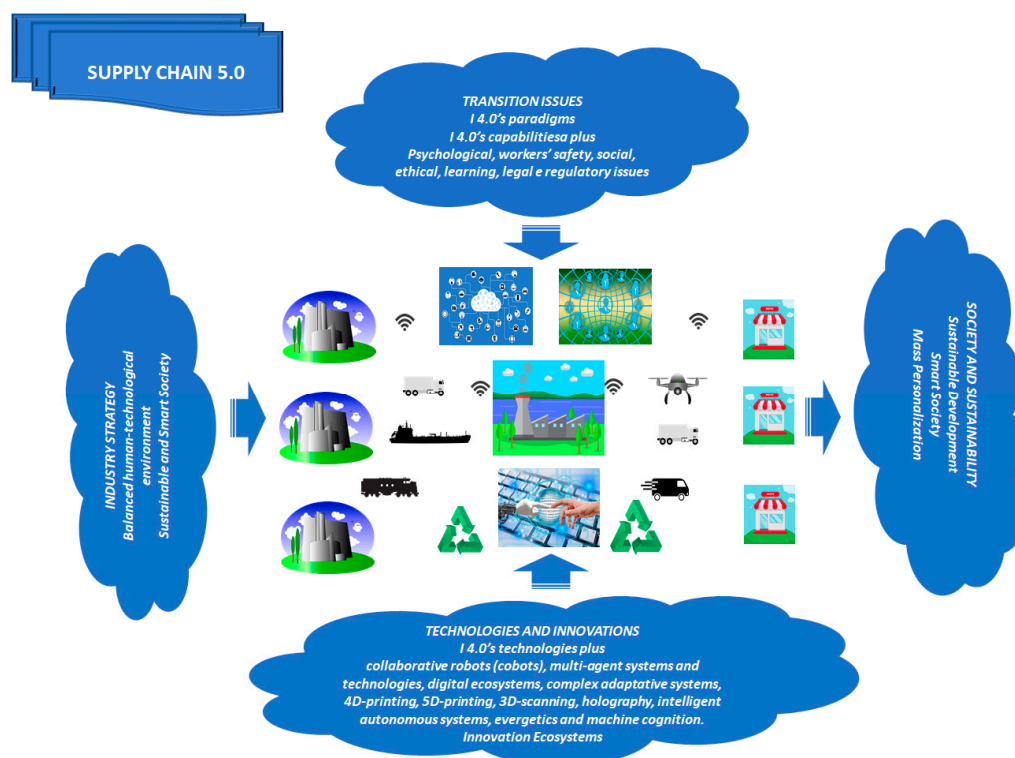


Figure 6. Supply Chain 5.0 framework and concept.

Therefore, based on Figure 6, Supply Chain 5.0 involves an industry strategy that pursues a balanced human–technological environment and a sustainable and smart society. This strategy is supported by technologies and innovation that include Industry 4.0's technologies and other emergent technologies as well as an innovation ecosystem. A Supply Chain 5.0 strategy also has some transition issues related to Industry 4.0's paradigms, Industry 4.0's capabilities, and other issues such as psychological, workers' safety, social, ethical, legal, and regulatory. As the main purpose, in terms of social and sustainable

aspects, Supply Chain 5.0 aims to allow a more sustainable, smart society. It also creates a mass personalization in terms of products and services of the supply chains.

#### 4. Conclusions

Industry 5.0 is still a visionary concept which aims to include the human, social, and sustainability aspects amid the current and highly focused technological scope of Industry 4.0. Although the literature is still scarce, there is a growing trend towards Industry 5.0 discussions by the academic and practical audience. Aiming to contribute to these discussions, this paper has presented the relationship between Industry 5.0 and supply chains, having as its basis a systematic literature review.

In the systematic literature review, it was possible to identify forty-one (41) articles related to the subject herein proposed. By the analysis of these articles through VOSviewer software, nineteen (19) words were clustered forming the four (4) main constructs conceptualized and discussed: **Industry Strategy, Innovation and Technologies, Society and Sustainability**, and **Transition Issues**. This answered the **RQ1** of this research, as described in the Introduction of this article.

To answer **RQ2** of this research, an alignment between Industry 5.0's constructs and the already available understanding of Supply Chain 4.0 was proposed. Although it is possible to identify some similarities between Supply Chain 4.0 and Supply Chain 5.0, the last adds more things in the four (4) constructs considered. Supply Chain 5.0 aims at mass personalization, adds revolutionary technologies, enables a super smart and sustainable society, and faces some transition challenges in its implementation, mainly linked to the paradigms established by the ongoing Industry 4.0 wave.

##### 4.1. Practical and Theoretical Implications

The practical implications of this work are relevant since organizations' leadership, policymakers, and other practitioners involved in supply chains, and mainly those currently working with Industry 4.0 programs, can benefit from this research in having clear guidance regarding the dimensions needed to structurally design and implement Industry 5.0's initiatives. Moreover, it can encourage practitioners to think about the benefits of Industry 5.0 in supply chains and their role with the aim to pursue a more sustainable and smart society. As identified in the literature review findings, Industry 5.0 may enhance strategic outcomes of supply chains by allowing mass personalization in products and services.

As theoretical implications, this article brings a novel contribution, being a starting point related to the relationship between Industry 5.0 and supply chains. This article also encourages further research in the area of supply chain and operations management in the context of this upcoming industrial revolution, by providing a clear set of constructs which form Supply Chain 5.0. The set of listed topics in Table 4 can also foster the development of new research programs linked to Industry 5.0 in supply chains. New theoretical and empirical studies may be deployed from the research. Surveys, case studies, and action research may support the validation of the constructs presented in this article as well as the addition of new ones. These new developments of research are crucial to a deeper understanding of the Industry 5.0 phenomenon in supply chains. Additionally, future reviews of the literature may also be of benefit to the subject of Supply Chain 5.0.

**Table 4.** Research agenda.

Industry 5.0's Constructs	Research Questions—Industry 5.0 and Supply Chains
Industry Strategy	<ul style="list-style-type: none"> <li>* How to deploy Supply Chain 5.0's strategy amid the paradigms of Industry 4.0?</li> <li>* How mature should organizations be before the rollout of the Supply Chain 5.0 strategy?</li> <li>* How to get alignment with the supply chain's members to develop a Supply Chain 5.0 program?</li> <li>* What are the strategic impacts of implementing a Supply Chain 5.0 program (e.g., sustainability, mass personalization, digital society)?</li> <li>* How can stakeholders in the supply chain get competitive advantages by implementing joint initiatives regarding Supply Chain 5.0?"</li> </ul>
Innovation and Technologies	<ul style="list-style-type: none"> <li>* What are the most beneficial technologies to create a Supply Chain 5.0 impact?</li> <li>* What are the key technologies of Industry 4.0 to create a proper scaffolding for the implementation of Industry 5.0's technologies?</li> <li>* How can technologies of Industry 5.0 be interoperable across the supply chain and interplay with society?</li> <li>* How can innovation ecosystems foster the deployment of Industry 5.0 programs in supply chains?</li> </ul>
Society and Sustainability	<ul style="list-style-type: none"> <li>* How can Supply Chain 5.0 interplay with society, to help the development of a super-smart society?</li> <li>* What are the benefits of the Supply Chain 5.0 approach for circular supply chains?</li> <li>* What are the benefits generated for individuals who interact with a Supply Chain 5.0?</li> <li>* How can Supply Chain 5.0 enhance the achievement of climate goals, helping to create a more sustainable environment?</li> <li>What is the role of the supply chain's members in the development of Society 5.0 and sustainable development?</li> </ul>
Transition Issues	<ul style="list-style-type: none"> <li>* What are the main barriers to the transition from Supply Chain 4.0 to Supply Chain 5.0?</li> <li>* Which capabilities must be developed before the implementation of Supply Chain 5.0's programs?</li> <li>* What are the triggers to implement a transition strategy from Supply Chain 4.0 to Supply Chain 5.0?</li> <li>* How can the stakeholders involved in supply chains impact a transition program?</li> </ul>

#### 4.2. Limitations and Research Agenda

Although this paper presents relevant insights, further research is required to overcome the limitations related to the validation of the constructs herein proposed. As the literature is still scarce and incipient, more constructs may be added in the future as the understanding of Industry 5.0 evolves.

Therefore, there is a fruitful field of research to be explored in both empirical and theoretical sides about the future supply chains in the context of Industry 5.0. With the purpose to help in the guidance of these future studies, this article also proposes a research agenda which is not limited to some research questions based on the four (4) constructs identified in this study. This closes the article and answers **RQ3**, which was presented in the Introduction section.

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