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TOPICAL REVIEW

Enabling Technologies to Support Supply Chain Logistics 5.0

BEATRIZ ANDRES[1], **MANUEL DIAZ-MADROÑERO**[1], **ANTONIO LUCAS SOARES**[2], **AND RAUL POLER**[1]

[1]Research Centre on Production Management and Engineering, Universitat Politècnica de València, 46022 Valencia, Spain
[2]Faculty of Engineering, INESC Technology and Science (INESC TEC), University of Porto, Campus da FEUP, 4200-465 Porto, Portugal

Corresponding author: Beatriz Andres (bandres@cigip.upv.es)

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ABSTRACT Industry 5.0 complements the Industry 4.0 approach by enabling the transition of industry digitization to a sustainable, human-centered and resilient paradigm. This paper delves into the exploration of enabling technologies that facilitate both Industry 4.0 and Industry 5.0 in the context of supporting supply chain (SC) logistics. The paper defines the principles of Logistics 5.0, which focuses on smart logistics systems for customized distribution, transportation, inventory management and warehousing by emphasizing interconnectivity, digitization, and optimization across SC operations. The traditional logistics framework requires innovative solutions grounded in emerging Industry 5.0 technologies capable of capturing and processing extensive datasets to empower decision-making based on information and knowledge. A comprehensive research has enabled to critically analyze enabling Industry 5.0 technologies by assessing their application status through real-case scenarios within SC Logistics 5.0. Furthermore, the paper identifies research gaps in the reviewed technologies by outlining promising areas for each Industry 4.0 technology. This guidance aims to direct future studies toward the practical application of technologies in supporting Logistics 5.0.

INDEX TERMS Industry 4.0, industry 5.0, logistics 5.0, supply chain, sustainability, technologies.

I. INTRODUCTION

One of the main objectives of industrial production and logistics is to meet customer demands, which are ever-changing because consumers demand individualized products in short delivery times [1]. With globalization, meeting consumer needs has become a challenge, and companies need new forms of production and logistics to avoid increasing costs and competitive disadvantages. Moreover, the new production and logistics era has to deal with current global business environments characterized by being unpredictable and competitive [2]. The incorporation of novel technologies will enable enterprises to respond and adapt to disruptive events by allowing sustainable recovery to return to the state before disruption, or to attain new better performance [3]. In this regard, Industry 4.0 and 5.0 are changing enterprises and supply chains' (SCs) strategies through new ways of managing production and logistic processes, creating new opportunities to achieve flexible processes and producing the personalized products demanded by consumers [4]. The responsiveness, agility and resilience of SCs can, therefore, be achieved according to Industry 4.0 and 5.0 principles via

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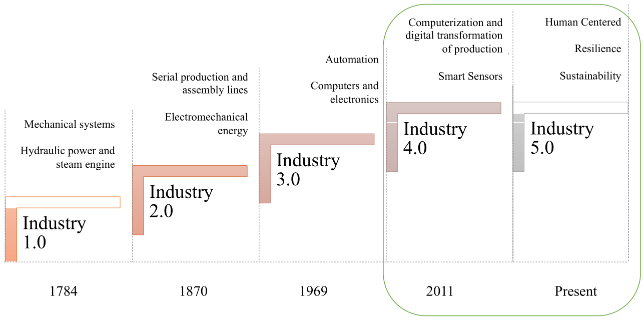


FIGURE 1. Industrial revolution evolution.

the connection of processes in a network where vast amounts of data are processed. Such information will be useful for decision making in logistic processes by allowing SC enterprises to increase their recovery capacity to face disturbances.

The Industry 4.0 concept was designed as a program to improve the manufacturing industry's productivity [5]. Throughout history, social, economic and technological transformation processes called industrial revolutions have taken place (FIGURE 1). Today's current industrial revolution evolution is starting to be based on Industry 5.0, which includes Industry 4.0 principles, but evolves on its ''objectives to leverage the creativity of human experts in collaboration with efficient, intelligent and accurate machines'' to obtain human-centered solutions compared to Industry 4.0 by covering long-term resilience and ensuring sustainable principles.

Many authors define Industry 4.0 as a global transformation of the manufacturing industry due to the introduction of digitization and the Internet, which has resulted in improvements to processes of design, manufacturing, logistics, operations, product services and systems [6]. The term Industry 4.0, or the fourth industrial revolution, refers to the use of recent digital technologies in industrial production. These technologies are often interconnected and allow new and more efficient processes and lead, in some cases, to the production of new goods and services. Many associated technologies range from developments in machine learning (ML) and data science, which allow increasingly autonomous and intelligent systems, and low-cost sensors that support the Internet of Things (IoT) [7]. According to [8], the technological pillars that stand out in Industry 4.0 are: (i) robots; (ii) simulation of integration systems; (iii) the IoT; (iv) artificial intelligence; (v) cybersecurity; (vi) cloud computing; (vii) 3D technologies; (viii) augmented reality; (ix) big data. More recently, the work of [9] has complemented the following Industry 4.0 technologies: (i) cyber-physical systems (CPS); (ii) automated guided vehicles (AGV); (iii) track and trace (T&T) systems; (iv) machine-to-machine (M2M); (v) smart products; (vi) blockchain; (vii) Radio Frequency Identification (RFID).

The objective of Industry 4.0 does not focus on the potential role that SCs can play in the service of society and by taking into account our planet's environmental limits. And so it is that the Industry 5.0 concept arises, whose main objective is to provide solutions for SC's productive and logistical problems with a resilient, sustainable and people-oriented vision [10], [11]. Hence the aim is to eliminate or reduce the possible effects of negative externalities, and to ensure economic growth, by means of society's greater well-being, ecological transition, digitization, sustainable growth, and the resilience of companies and institutions, especially in the current business environment that is characterized by multiple consequences due to the effects of the COVID-19 pandemic.

According to [10], Industry 5.0 should not be understood as a chronological continuation of Industry 4.0. It corresponds to an initiative that frames industry and society's new trends and needs. Therefore, Industry 5.0 complements and extends the distinctive features of Industry 4.0.

There is generalized concern about meeting customer demand, which is characterized by highly personalized products and short delivery times. To achieve this, academics and practitioners focus their efforts on optimizing the logistics system by making it more reliable, flexible and agile, and definitively more resilient, to unforeseeable natural disasters and man-made catastrophes. Logistics, as we know it, requires new solutions that follow the Industry 5.0 trend to increase human interaction, enhance SCs' resilience and follow sustainable principles. Thus logistics must evolve toward the application of emerging technologies linked with the ability to capture and process vast amounts of data and to perform actions based on the information that results from such processing. These solutions are necessary for the uptake of Industry 5.0 and will henceforth be named Logistics 5.0 in this paper.

The guiding research question is: *What is the state of research into the* technologies *that support Logistics 5.0 to improve human-centeredness, resilience and sustainability in SCs?* We divided it into three subquestions:

- *RQ1. What technologies potentially support Logistics 5.0?*
- *RQ2. What is the status of applying these technologies in real cases?*
- *RQ3: What research gaps can be addressed by future research regarding Logistics 5.0 technologies?*

The primary analysis limited the considered technologies to those with a clear potential to improve Logistics 5.0 SC processes, resilience and sustainability. This study also analyzes the limitations of the reviewed articles, the extent to which the proposed technologies have been implemented into the industry, and future research lines. Finally, a set of tools of relevant application to support Logistics 5.0 is narrowed down by focusing on those that address both SC resilience and sustainability aspects. The article is organized as follows: Section II presents the theoretical background. Section III defines the review methodology. Section IV contains the results. Section V discusses the obtained results. Section VI concludes the paper.

II. THEORETICAL BACKGROUND

A. RESILIENCE

According to [12], SC resilience responds to SCs' adaptive capability to reduce the probability of facing sudden disruptions related to disturbances in flows of materials, products or services. We agree with [13] about academics and practitioners having to deal with new collaborative approaches that empower SCs against disruptions. This is done by applying new technologies from the Industry 5.0 scope and implementing them by considering that collaborative principles are key actions to achieve higher levels of visibility, agility and flexibility, which are extremely valuable SC capabilities during the recovery process [14], [15]. Moreover, integrated logistics capabilities enable the achievement of enhanced SC resilience. In line with this, the work of [16] highlights the importance of integrating logistic capabilities toward positive influences on SCs' resilience. It is worth highlighting the works of [17], [18], [19], [20], [21], and [22] that identify positive relations between logistics and SCs' resilience.

B. SUSTAINABILITY

Sustainable SC management is an approach that encourages companies to improve from a sustainability perspective, i.e., companies take care of integrating economic, social and environmental goals into SC processes [23], [24]. According to [25] and [26], a sustainable SC is based on the: (i) analysis of social aspects, and their quantification and integration with economic and environmental aspects; (ii) environmental risk management; (iii) a sustainability analysis in areas like transport and storage. The sustainability area is also related to logistics through the concept of reverse logistics and closed-loop SCs. According to [27], reverse logistics aims to increase the industry's sustainability with the recycling, remanufacturing or reprocessing of products, and the repair and safe disposal of products and components. When addressing Industry 5.0, SCs and sustainability, it is worth mentioning the work by [28], whose review highlights current knowledge of SCs 4.0 from the sustainability perspective.

C. HUMAN-CENTERED

The transformation of the industrial sector since Industry 4.0 emerged has been based mainly on the increasing digitization and interconnection of technologies like the IoT, cyber-physical systems (CPS), artificial intelligence (AI), the digital twin (DT), ML, collaborative robots, among others. In this context, concepts like Operator 4.0 [29] have appeared and are based on meeting their work needs by using technology in their workplaces. However according to [30], this promising perspective is now completely disconnected from the human factor point of view despite the fact that technological developments have fundamentally changed its role in productive systems. Industry 5.0 covers the human interaction by leveraging human expertise to collaborate with potent, clever and precise technologies [31]. This transformation requires constantly updating workers' knowledge [32] to optimize their performance in their current positions and to develop the skills they need to occupy the new positions that will be created because of the business environment's evolution [33], [34].

D. SUPPLY CHAIN 5.0

SC5.0 is characterized by a high interconnection level between physical and digital environments, where IoT sensors allow real-time information to be collected and transmitted throughout the chain. In addition, big data analytics (BDA), AI and cloud computing (CL) enable simultaneous decisions to be made for different processes to optimize overall SC performance in real time. Moreover, automation and robotics facilitate repetitive tasks and labor-intensive work without having to resort to human interventions [35]. With the exponential advance and interaction of digital technologies, SCs are expected to gain a higher degree of autonomy until they can think and act for themselves, but always with human customization, critical thinking and intelligence to enable human and machines to work collaboratively. As technological advances must be adopted in the different SC processes, close collaboration is required of all the involved actors and Industry 4.0 technologies. SC partners have to ensure the interoperability of systems and synchronize changes to receive the maximum benefits from transformation that must be comprehensive for both machines and humans [36].

E. LOGISTICS 5.0

Logistics 5.0 has emerged by underlining Industry 4.0 along with Industry 5.0 through developing smart logistics systems to meet consumer needs in today's connected, digitized and rapidly changing global logistics market environments [14]. Logistics 5.0 deals with not only customized distribution, transportation strategies inventory management and warehousing decisions, but also with the interconnectivity, digitization and optimization of processes, data, people and machines in all the logistics operations carried out in SCs, including transport, procurement and distribution processes, stock and storage spaces, shipping, route optimization, fleet management, and invoicing and payment. Logistics 5.0 includes five functional areas that are integrated with humans, which are: (i) data collection and processing; (ii) assistance systems; (iii) networks and integration; (iv) decentralization and service orientation; (v) self-organization and autonomy [27]. They facilitate improvement in different aspects of logistics, such as sustainability, efficiency, responsiveness to customers, better traceability and human-machine collaboration. Logistics 5.0 also allows greater flexibility, which supports mass customization. It also favors data exchanges in SCs, which will improve transparency and performance. The limitations of this process lie in the fact that companies become more vulnerable due to the cybernetic

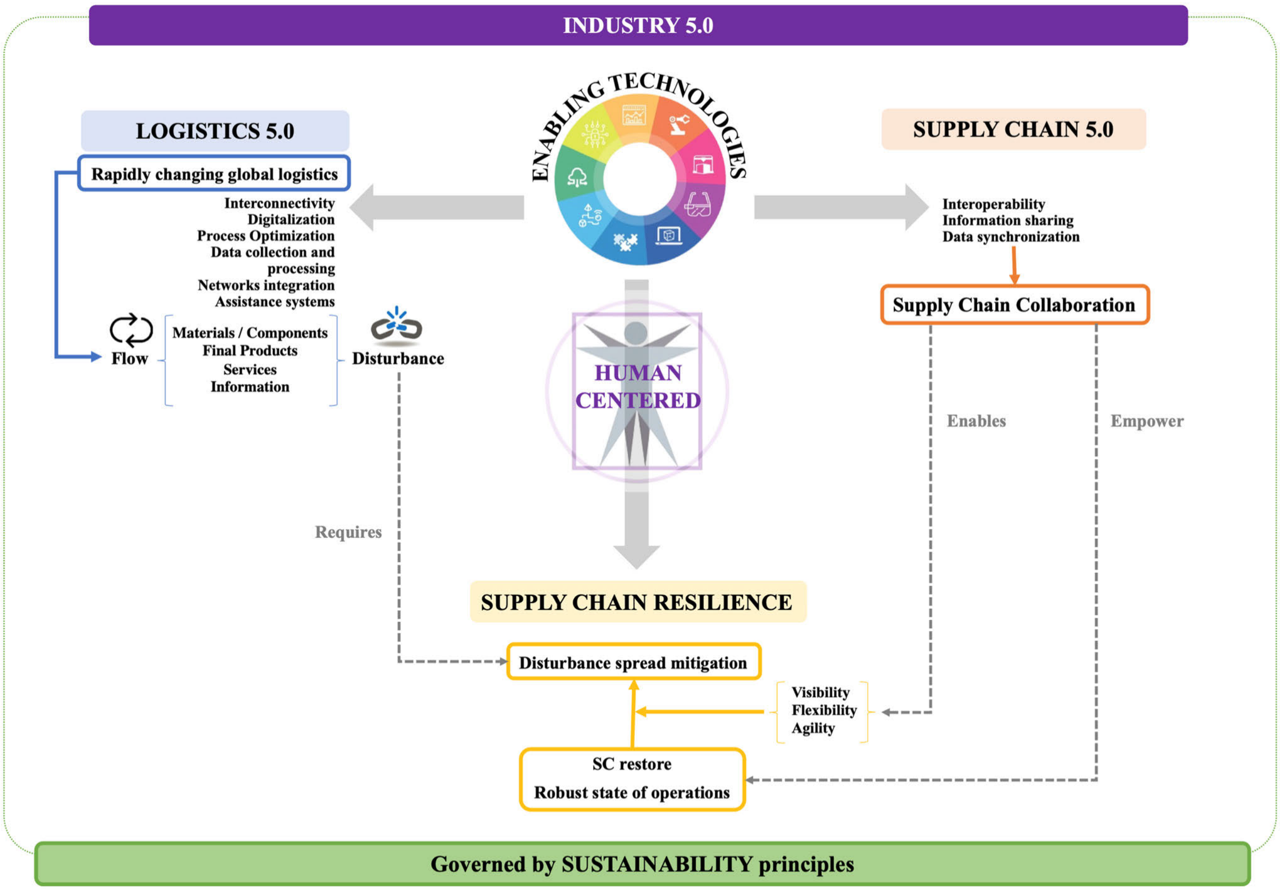


FIGURE 2. Industry 5.0 and logistics 5.0.

and physical risks that Logistics 5.0 entails [37]. Moreover, [37] highlights that the objective of Logistics 5.0 is not to replace humans in their jobs, but to avoid inaccuracies and to gain faster processes in which information can be effortlessly shared in real time. Thus the participation of people who control processes and any system failure will always be necessary (FIGURE 2).

III. RESEARCH METHODOLOGY

A systematic literature review was carried out to identify those papers proposing technologies that support Logistics 5.0. To generate the sample of articles, the suggestions of [38] and [39] were followed. The sample of articles was generated in six phases (FIGURE 3).

To start the search process, a review of secondary sources was performed to establish the conceptual framework. Accordingly, six relevant papers to the topic under study were found: [8], [9], [31], [39], [40], and [41]. A set of technology classes (see Figure 5, Section IV) was taken from the reviewed works, which was used as the base of the keywords employed to define the current review on enabling technologies to support SC Logistics 5.0. The reviewed authors also identified a set of gaps in their research works by accounting for the motivation of the current literature review.

The present systematic literature review was performed in two stages (FIGURE 3). In both stages, the Scopus database was used as the main source for the keywords search. The retrieved publications were published in journal articles and conference proceedings, which allowed access to the recent results in the area under study to be gained. The refinement process took into account publications from 2010 to 2020 because the term Industry 4.0 was coined in 2011 [5]. Our research work aimed to monitor how I4.0 and I5.0 technologies have been applied since then to the present day in the logistics context.

The first stage of the search proceeded by using: (i) the keyword "logistics"; (ii) the keywords referring to the classes of technologies found; (iii) the keywords of the industrial paradigms to which we refer, namely Industry 4.0 and Industry 5.0 (see Table 1). This first review limited the search to only those technologies associated with Logistics 5.0, which is the topic that concerns us. Following Phases 1 to 4 (see Figure 3), the first search stage resulted in 20 papers.

The second search stage was done to complete the literature review with papers directly included that were not retrieved from the first stage search. This second round resulted in 18 papers that were directly included. In Phase 5 (see Figure 3), we considered the reverse logistics topic

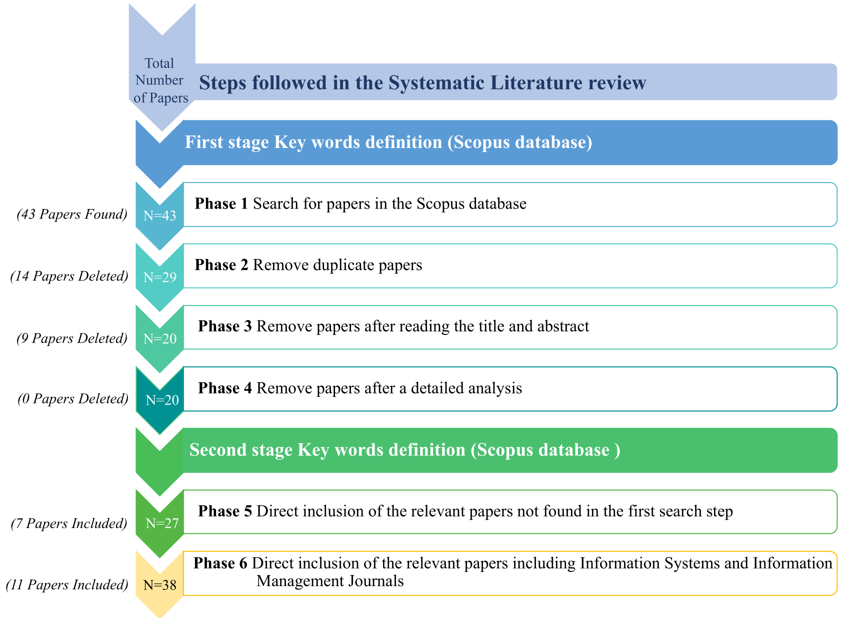


FIGURE 3. Papers selection process.

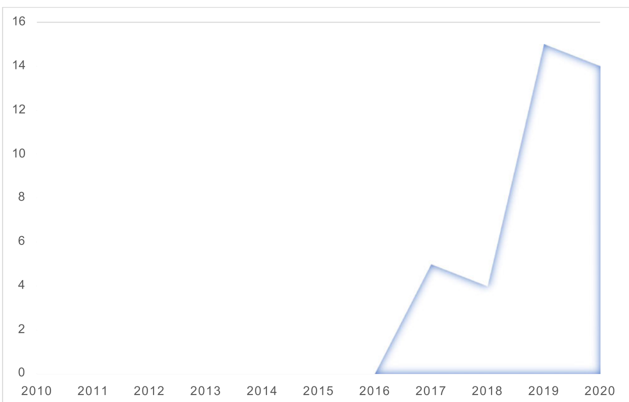


FIGURE 4. Number of papers throughout the search period.

which, according to [9], is an important enabler for the transition to the next industrial revolution Industry 5.0 along with sustainability and SC resilience. Moreover, optimization is a crucial research method for solving Industry 4.0-related decision-making problems [9]. Accordingly, in Phase 5 we also considered the optimization models, metaheuristics and matheuristics keywords (see Table 1). Finally, Phase 6 took into account the information systems as a key point in Logistics 4.0 or 5.0 [42], [43]. Nevertheless, we have to point out that we found no papers with the keywords proposed in combination with (''4.0'' OR ''5.0''). So this last filter was removed and 11 new relevant papers appeared in information technology, information systems and data management journals.

A. BIBLIOMETRIC RESULTS

The distribution of articles over time appears in Figure 4. We can deduce that research into the topic was in its early stages during the 2016-2018 period. More attention was paid to the adoption of the topic of Industry 5.0 in Logistics from 2018 onward. The publications related to our study topic peaked in 2019 and 2020, and this upward trend is expected to continue in forthcoming years.

TABLE 1. Systematic literature review: Keywords definition.

Literature review Phase 1. Keywords
"logistics" AND "business intelligence" AND ("4.0" OR "5.0")
"logistics" AND "big data analytics" AND ("4.0" OR "5.0")
"logistics" AND "blockchain" AND ("4.0" OR "5.0")
"logistics" AND "internet of things" AND ("4.0" OR "5.0")
"logistics" AND "artificial intelligence" AND ("4.0" OR "5.0")
"logistics" AND "machine learning" AND ("4.0" OR "5.0")
"logistics" AND "digital twins" AND ("4.0" OR "5.0")
"logistics" AND "hybrid intelligence" AND ("4.0" OR "5.0")
"logistics" AND "social media" AND ("4.0" OR "5.0")
"logistics" AND "RFID" AND ("4.0" OR "5.0")
"logistics" AND "cloud computing" AND ("4.0" OR "5.0")
"logistics" AND "edge computing" AND ("4.0" OR "5.0")
"logistics" AND "augmented reality" AND ("4.0" OR "5.0")
"logistics" AND "virtual reality" AND ("4.0" OR "5.0")
"logistics" AND "cobots" AND ("4.0" OR "5.0")
Literature review Phase 5. Keywords
"logistics" AND "reverse logistics" AND ("4.0" OR "5.0")
"logistics" AND "optimization models" AND ("4.0" OR "5.0")
"logistics" AND "metaheuristics and matheuristics" AND ("4.0" OR "5.0")
Literature review Phase 6. Information Systems/Management Journals and Keywords
"logistics" AND "computers in industry" AND ("4.0" OR "5.0")
"logistics" AND "information management" AND ("4.0" OR "5.0")
"logistics" AND ("industrial management" OR "data systems") AND ("4.0" OR "5.0")
"logistics" AND "computers in industry"
"logistics" AND "information management"
"logistics" AND ("industrial management" OR "data systems")

Table 2 summarizes the contribution of the articles from each journal. A set of 38 papers from different journal

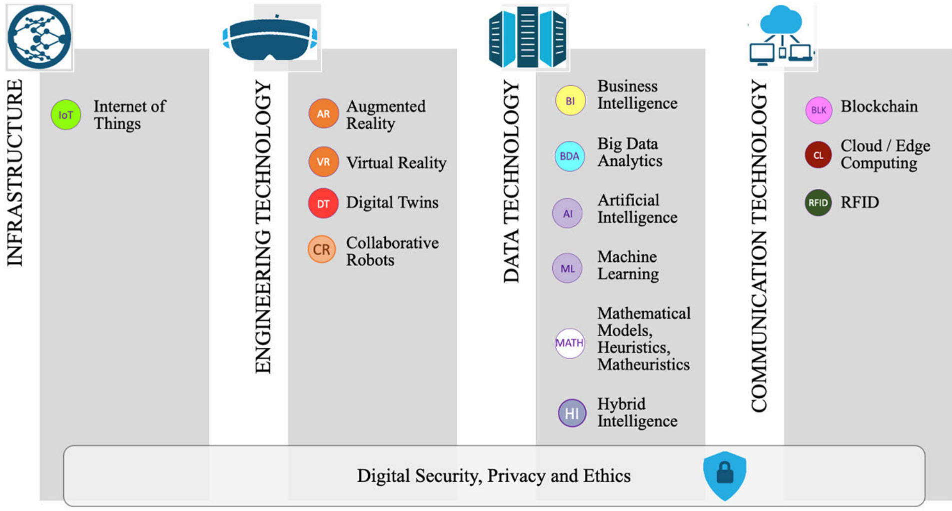


FIGURE 5. Conceptual model taxonomy.

TABLE 2. Number of papers per journal.

Literature review Phase 1. Keywords	
Applied Sciences	6
Procedia Manufacturing	3
Association for Computing Machinery	2
Sustainability	2
Advances in Manufacturing	1
Computers in Industry	4
Contributions to Economics	1
Engineering Management in Production and Services	1
Proceedings of 2019 8th International Conference on Industrial Technology and Management	1
IEEE International Conference on Emerging Technologies and Factory Automation	1
IFAC-PapersOnLine	1
Industrial Management & Data Systems	3
International Journal of Business Analytics	1
International Journal of Information Management	3
International Journal of Information Management Insights	1
International Journal of Logistics Management	1
International Journal of Production Research	1
IOP Conference Series: Materials Science and Engineering	1
LogForum	1
Open Engineering	1
Production	1
Production Planning and Control	1
TOTAL	38

categories was reviewed. The sources found in the journal Applied Sciences in the multidisciplinary engineering category, Computers in Industry in the computer science and interdisciplinary applications category and Industrial Management & Data System in the engineering, industrial and computer science, interdisciplinary applications category, are highlighted. There are research categories of great interest in the study topic that are about analyzing enabling technologies to support SC Logistics 5.0.

IV. A SYSTEMATIC LITERATURE REVIEW ON TECHNOLOGIES TO SUPPORT LOGISTICS 5.0

In order to highlight the contribution of this work, a detailed review of the papers was carried out and resulted in a tertiary analysis: [8], [39], and [41]. This tertiary analysis focused on Logistics 4.0 because no literature review works referring to Logistics 5.0 were found. Reference [8] seeks the importance of Logistics 4.0 for its support and use in the following technological applications: resource planning systems, warehouse management systems, transport management systems, intelligent transport systems and information security systems. Reference [41] present 12 criteria for a logistics center 4.0, linked with what the author refers to as technologies[1] that support Logistics 4.0, namely: intelligent management, zero-emission, intelligent mobility, cargo exchange platforms, digital information platforms, intelligent transport systems, information security, real-time location systems, autonomous vehicles, intelligent warehouses, logistics center alliances and digital connectivity. Reference [39] carry out a systematic literature review on the new logistics systems, in which some technologies for Logistics 4.0 are identified: IoT, big data, CL, mobile-based systems and social network-based systems. These authors mention other technologies, of which blockchain (BLK), additive manufacturing and immersive technologies stand out. Finally, these authors analyze and propose a classification of technologies into three subcategories: technologies to generate information; technologies to process information; technologies to use information. They all appear in the Logistics 4.0 context. Reference [39] also identify the gaps encountered within the Logistics 4.0 scope, which are answered in the present paper. Therefore, this paper goes one step further by addressing the novel area of Logistics 5.0, which also includes new technologies and characteristics of Industry 5.0, and it intends to determine the real implementation degree of Logistics 5.0 in real supply chains.

As part of this tertiary review, Table 3 summarizes the methodology and sample overlap of the reviews

[1] [41] names these as "technologies", which poses a problem for our conceptual framework. We prefer to see these as "systems" (applications of technologies).

TABLE 3. Comparison of the literature reviews related to enabling technologies to support supply chain logistics 5.0.

Authors	Method	Sample Overlap	Limitations	Future Research Lines
[8]	Narrative review	0	Not specified	Develop a multilayered framework that can identify the phases, processes, technical requirements and respective levels of integration, in addition to policies that involve the partners who provide support in the diagnosis, analysis and definition of the appropriate path to organizational growth and its growing achievement of the Industry 4.0 and Logistics 4.0 paradigms
[41]	Narrative review	4.5%	Prior knowledge in the field is limited. So implementing the results can be a challenge	Expand the criteria for Logistics 4.0 centers and test the results in a real-life example
[39]	Systematic literature review	4.5%	Only articles from peer-reviewed journals are considered according to keywords. Only primary logistical tasks are considered, not the supply chain. Only the articles from industry and commerce are considered	Encourage future research in the intelligent logistics systems area

TABLE 4. Industry 5.0 technologies definition.

Category	Technology	Definition	Author
Infrastructure	Internet of Things (IoT)	It refers to the software, sensors and devices connected to computer networks to enable data exchanges with other devices, systems, applications and users, the purpose of which is to create a network infrastructure.	[8][42] [44] [45] [46][47][48] [49] [50] [51] [52] [53] [37] [39] [54] [55] [56]
Engineering Tech.	Augmented Reality (AR) and Virtual Reality (VR)	AR is the process of layering digital data on the real world in the form of computer-generated content, such as text, video or animated three-dimensional models VR aims to engage the user in an immersive experience that is completely closed off from the real-world environment by employing a high-end user-computer interface to enable real-time simulation and interactions through multiple sensorial channels	[44][57] [58] [59] [60]
	Digital Twins (DT)	Digital representation of a real-world entity or system by modeling the people, processes and things linked with the real-world twin and incorporating data about real-world operations	[57][61]
	Collaborative Robots (CR)	A cobot is a robotic device that manipulates objects and works directly alongside humans with no safety fencing or barriers on the manufacturing floor	[42] [62]
Data Tech.	Business Intelligence (BI)	A set of methodologies, applications, practices and capacities focused on the creation and management of information that allows the organization to make better decisions	[46][63] [64]
	Big Data Analytics (BDA)	Large datasets, mainly with volume, variety, speed and/or variability characteristics, which require a scalable architecture for efficient storage, handling and analysis purposes	[65] [27] [45] [66] [49] [51] [37] [39] [55]
	Artificial Intelligence-based technologies (AI)	A set of technologies built on AI models and techniques, such as machine learning, virtual agents, natural language generation, semantic technology, etc. The aim is to provide services or insights that are otherwise difficult or impossible to achieve by humans alone or by traditional technologies	[67][68] [66] [69]
	Machine Learning (ML)	It refers to the automated detection of patterns in datasets. ML tools aim to increase the efficiency of algorithms by ensuring the ability to learn and adapt based on BDA	
	Mathematical programming (MATH)	Mathematical programming approaches for modeling replenishment, production and delivery plans to solve them. Mathematical programming models are based on research optimization techniques. Heuristic methods are used to solve computer problems by means of parameters given in advance by users. Matheuristics optimization algorithms derive from the interoperability of metaheuristics and mathematical programming techniques	[46] [70] [68] [71] [39] [69] [72] [73][74]
	Hybrid Intelligence (HI)	The ability to achieve complex goals by combining human and artificial intelligence to, therefore, obtain superior results to those that each one could have accomplished separately, and to continuously improve by learning from one another	[75]
Communication Tech.	Blockchain (BLK)	It is a distributed decentralized database used to maintain a continuously growing list of records called blocks. Each block contains a time stamp and a link to a previous block. A general ledger in which all the transactions between two parties are efficiently recorded, where records are secure and can be verified during each transaction	[42][76] [77][37] [53] [78]
	Cloud Computing (CL)	A consumer-oriented distributed computing system that consists of a collection of virtualized and interconnected computers that are dynamically provisioned and presented as one unified computing resource or more according to a service level agreement negotiated between the service provider and the consumer	[45][79][80] [81] [82] [50][37] [39]
	Radio Frequency Identification (RFID)	This technology identifies, detects and locates items, and sends data to a computer that can collect and analyze this relevant information	[44] [66] [77] [81] [54]

mentioned above with the present paper. Therefore, the work performed in this paper is feasible because the sample overlap is less than 4.5%, and even the total overlap of this study with the literature reviews is lower than 9%.

In order to create a classification of emergent technologies within the Industry 5.0 scope, the work by [9] was examined. In their paper, the authors propose four research disciplines in the Industry 4.0 context. Our paper adopts these four disciplines to classify Logistics 5.0 technologies to support

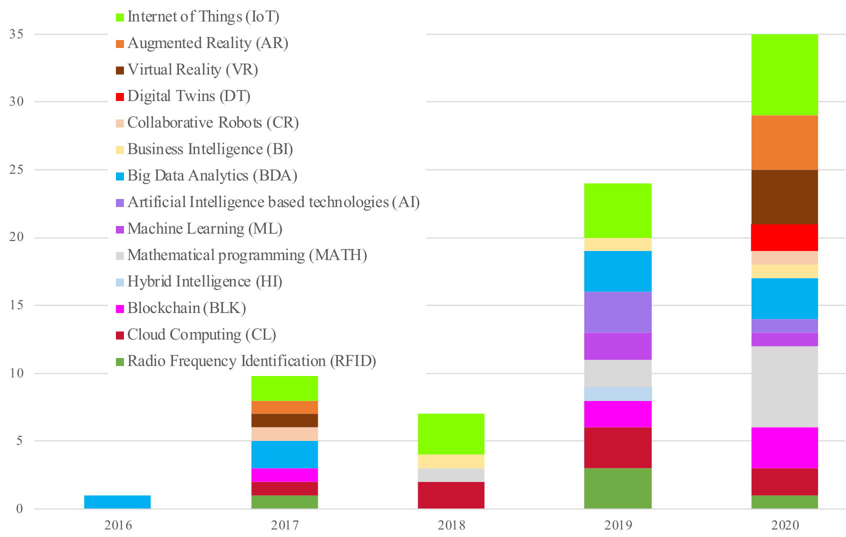


FIGURE 6. Distribution of technologies per year during the reviewed period.

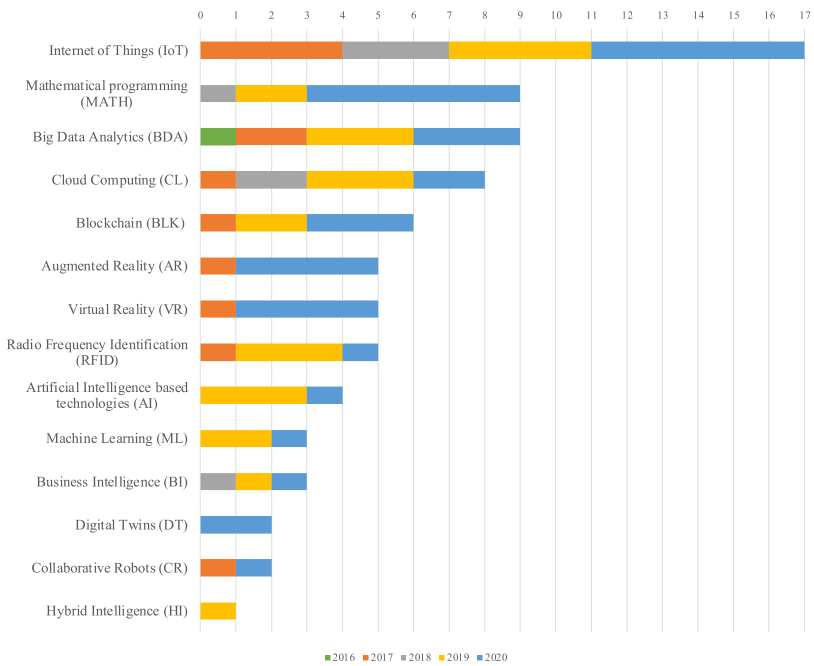


FIGURE 7. Number of papers per year in each technology.

resilient SCs (FIGURE 5). In Table 4, Industry 5.0 technologies are defined and the authors retrieved from the literature review are listed.

Taking into account the technologies defined in the conceptual model taxonomy, the graph represented in FIGURE 6 shows the distribution of the technologies addressed within the Logistics 5.0 scope during the reviewed period. At the beginning of the studied period, the IoT, BDA, and CL technologies are the most addressed to implement the I4.0 concept in Logistics. From 2019, new technologies related more to I5.0 are implemented in Logistics, including AR and VR, DTs, CR, AI or ML. FIGURE 7 compares the studies published per technology type, and displays that the most studied area in Logistics 5.0 is the IoT, followed by the MATH and BDA. CL is beginning to stand out, while the HI, DT and CR technologies are still in their early stages in the Logistics 5.0 area.

Table 5 presents the analysis results of each technology by indicating: (i) the state of research on technologies to support Logistics 5.0 processes; (ii) the addressed logistic

TABLE 5. Logistics 5.0 technologies: state of the art, sustainability principles, barriers and degree of application.

Tech-nology	State of the Art	Addressed Logistic Process	Sustainability Principles	Barriers	Appli-cation
IoT	There is a high potential in IoT technology given the wide range of the applications on networks to enable data exchanges with other devices, systems, applications and users, the purpose of which is to create a network infrastructure. The IoT can be used in different Logistics 5.0 areas, but the IoT also has its disadvantages. Of the technologies analyzed in this systematic literature review, the IoT is the best documented one, and shows real examples of application. The IoT is, therefore, considered a fundamental technology to transform traditional logistics into Logistics 5.0. Finally, the integration of CPS and the IoT into logistics allows the real-time monitoring of inbound and outbound logistic processes.	- Cross-docking - Customer satisfaction - E-commerce - Fleet management - Just-in-Time (JIT)/Just-in-Sequence (JIS) - Kanban - Machinery and material handling equipment - Material flows - Planning and controlling tasks - Preparing and controlling packaging and orders - Production optimization - SC visibility - Traffic monitoring track shipments - Vendor-managed Inventory (VMI) - Warehouse Management	The IoT positively impacts business sustainability and efficiency because, by automating or robotizing logistics operations and processes, time losses, real-time management, CO_2 emissions, staff hours and fuel demands are reduced.	- Unknown level of implementation costs - No guaranteed returns from applying the IoT - Lack of standards - Risk of rapid obsolescence in IoT terms - Data security - Lack of adequately qualified labor - Required input data and events at the right time, of quality and in the proper place	◕
AR VR	Although many Industry 4.0 technologies have been applied to some logistic processes, AR and VR technologies are still in their early application stages. AR, VR and DT applications to other research areas are found in (Burghardt et al., 2020)[59]. The authors propose a method for programming industrial robots using VR. Although the paper does not mention logistic operations, the essence of the method is worth noting for considering AR and VR within the logistic activities scope, such as picking, warehouse or inbound logistics.	- Logistics infrastructure - Packaging and containers - Shipments - Vehicle loading operations - Warehouse picking - Warehouses and distribution centers	[61] states that AR and VR improve the reuse or recycling of food packages, reduce food loss, and support package reuse and recycling. AR and VR simulate logistic scenarios to be created with no need for physically creating real scenarios.	- Costs of implementing AR and VR - Investments in technological and human resources - Cost-sensitive nature of many logistics activities may explain why few companies have so far been willing to make the necessary investments. - Required input data and events at the right time, of quality and in the proper place	◔
DT	DT technology is still in its early application stages. Some applications are seen in (Bécue et al., 2020)[58], which consider using DTs to support factories of the future, and includes examples like transport robots for logistics, logistic systems between different factories and complete factories. The DT is related to the IoT, and combines digital models and scenarios with algorithms and simulations to tackle the enormous amount of data from different sources to make dynamic and real-time dimensions [61]	- Dispatching - Global logistics networks - Inventory routing - Logistics infrastructure - Replenishment - Shipments - Vehicle loading operations - Warehouses and distribution centers	DTs allow models based on reality for simulating logistic scenarios to be created with no need for physically creating real scenarios. This would be costly and not sustainable over time because the new real situation could not achieve the expected results, and all the performed work and associated expenditure would be lost.	- Costs of implementing the DT - Initial investments in technological and human resources - Lack of adequately qualified labor - Required input data and events at the right time, of quality and in the proper place	◔
CR	CR technology should be treated as a means of devices that manipulate objects and collaborative work with humans to facilitate repetitive tasks and labor-intensive work, and safely co-exist in the same space. The Operator 4.0 concept appears, and is based on meeting operators work needs by using technology in workplaces.	- Picking - Inbound logistics - Warehouse - Cross-docking	-	- Lack of works published about the application of cobots within the Logistics 5.0 scope.	○
BI	The central BI system consolidates different data that are both external (mobile phones, social networks,	- Distribution costs - Fleet management	Make better decisions in	- Despite this technology being used by SMEs, managers are aware that	○

TABLE 5. *(Continued.)* **Logistics 5.0 technologies: state of the art, sustainability principles, barriers and degree of application.**

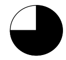
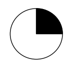
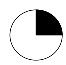
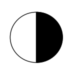
Tech-nology	State of the Art	Addressed Logistic Process	Sustainability Principles	Barriers	Appli-cation
	GPS) and internal (sales records, HR, financial, inventory, CRM) sources. (Bordeleau et al., 2020) [64] and (Nagy et al., 2018) [46] agree that BI technology can be applied to Logistics 5.0 to obtain excellent profitability and productivity in companies because it helps to make better decisions in short times based on real data. Moreover, (Bordeleau et al., 2020) [64] highlight that a measurement method is necessary to know the commercial value that BI provides SMEs with, which is another research gap. With the analyzed articles, it can be concluded that there are no indications of applying BI to Logistics 5.0 because they only refer to production operations.	- Reverse logistics - Storage	short times based on real data	employing more sophisticated BI software can increase their profits - Monetary barriers appear, which are mostly due to SMEs not being able to afford BI technologies - There is still a long way to go to reach the level of large companies, which have the possibility of investing in both trained personnel and the latest technological updating - Although managers understand the importance of using BI, areas of improvement in Logistics 5.0 are not clear	
BDA	Instantaneous information exchange, automated solutions and real-time BDA are among the characteristics required to efficiently apply Logistics 5.0. By running the analysis, we conclude that researchers see a promising future for BDA and its application to Logistics 5.0. Accordingly, BDA allows a large volume of data and complex data to be managed to increase business performance, improve decision making and gain a competitive advantage. Nevertheless, more attention must be paid to the reliability and quality of information [39]. Although we refer to a reliable example of a BDA application to Logistics 5.0 [27], more real examples need to be published in the literature. Both (Correa et al., 2020) [55] and (Corrêa et al., 2020) [84] identify a limitation related to lack of a robust financial analysis. Here confidentiality in companies' data commands makes this economic analysis type very complicated.	- E-commerce - Inventory management - Material handling - Optimal routes for transporting materials and products - Transportation	One very important aspect in Logistics 5.0 is circular economy. (Strandhagen et al., 2017) indicate that the BDA analysis, together with CPS, allow the evaluation of products' end-of-life recovery.	- Some of the challenges that we identify are those related to not having the necessary tools to handle large amounts of data, and the cost of obtaining advanced technology to apply BDA - (Bukowski, 2019) [51] points out that information is subjective because it depends on not only data, but also on the interpretation process - The logistics sector places special emphasis on the expected return time of investments in BDA - The main limitations are high investments in software and hardware, followed by high investments in human resources	
AI	AI enables logistics operators to see, understand and interact with the world in new efficient way. (Dossou, 2019) [77] addresses implementing AI in the logistics area by using robots to perform the most difficult tasks and cobots to help workers with specific tasks, and it achieves significant efficiency in these processes. Although this is an emerging field research that requires much more research, researchers and practitioners believe that the future of AI in Logistics 5.0 has a very high potential. Additionally, when looking at current industry trends, researchers see the need to intensify AI use in practical applications. Finally, in the literature it is very difficult to identify the level of maturity that companies need to implement AI, especially in Logistics 5.0. So this can be considered a research gap.	- Monitoring goods' content - Storage operations - Transport management operations - Warehouse management	Adjusting a product's storage conditions in the selected warehouse segment to help to save energy.	- The survey results of (Toboła et al., 2019)[66] indicate that very few companies use AI in practice because of the high cost of and marked difficulty to implement AI, and the need to train future employees in this technological challenge - (Woschank et al., 2020) [69] also indicate some barriers for applying AI, including the low confidence levels of stakeholders in industries, the thought of AI applications operating in black boxes, or providing little or no discernible information about how to achieve their results - Lack of trust in AI is a challenging barrier for adopting AI [75]	
ML	ML comes over as predictive software to detect failures. By means of a systematic literature review, (Woschank et al., 2020) [69] identify that most studies are based on concepts, laboratory experiments or are in a very early testing phase. Therefore, the aim of another research opportunity is to apply ML technology, which is still in its early development stages.	- Predictive maintenance of logistic processes - Shipments - Storage - Transport	-	Many barriers are still to be bridged, including: - Studying the competitive advantages offered by ML - The required economic investment - No measures about the profits of implementing, or not, ML in SMEs	
MATH	Most of the technologies, which have been analyzed in detail, use mathematical approaches like algorithms or heuristics. In BI technologies, intelligent databases and learning algorithms allow efficient data analyses to make smart decisions about logistic problems. With BDA, the use of algorithms enables predictive analyses that employ mathematical models and algorithms to determine and evaluate alternative decisions. Using IoT data collection improves logistics planning by utilizing control models, algorithms and heuristics. AI and ML are technologies that employ intelligent algorithms to allow computers and machines to function in an intelligent way. As analytical methods are not completely efficient in	- E-commerce - Inbound logistics - Just-in-Time (JIT)/Just-in-Sequence (JIS) - Kanban - Online-to-Offline (O2O) - Plant supply process - Routing, assignment and scheduling - Vendor-managed inventory (VMI)	Improved savings algorithms contribute to define the real-time logistics services and decision support systems that enable increased efficiency and lower carbon emissions to achieve sustainability principles.	- Requires handling a large amount of data and analytical models are complex to build - Solvers require longer computation times, which makes solving algorithms very difficult in reasonable times for enterprises	

TABLE 5. *(Continued.)* **Logistics 5.0 technologies: state of the art, sustainability principles, barriers and degree of application.**

Tech-nology	State of the Art	Addressed Logistic Process	Sustainability Principles	Barriers	Appli-cation
	finding suitable solutions for such problems, a future research line in the topic under study is to propose heuristic and matheuristic approaches that deal with highly complex logistic plans that involve managing large amounts of data. Matheuristics could give logistic enterprises and confer global supply SCs shorter computation times when solving NP-hard and complex problems with different stakeholders distributed along the value chain [71].				
HI	No signs of application have been found in Logistics 5.0. Therefore, more research is needed, especially to gain more in-depth knowledge about these technologies in Logistics 5.0. Nevertheless, it must be stated that the use of hybrid approaches in logistics would improve the classic problem-solving methodology. HI could overcome the efficiency of heuristics or metaheuristic methods, implemented to solve logistics distribution and to supply management applications [85]	-	-	-	○
BLK	(Markov & Vitliemov, 2020) [53] explain that the BLK technology has the significant potential to improve Logistics 5.0 processes through the possibility of simultaneously sharing information and documents among all SC companies. The use of BLK and Internet portals for all SC companies would increase cost savings because real-time information and documentation would be shared by all the participants. The main benefit of BLK is the security that it guarantees for being an encrypted system, which prevents registered information being manipulated.	- Supply chain visibility and information in real time	Physical records (paper) are certainly eliminated and completely replaced with reliable digital records throughout the SC. However, (Kodym et al., 2020) [37] highlight an ecological impact risk because each verification transaction in BLK requires high computing power and, therefore, considerable energy use.	- Faulty data possibly entering BLK portals. This would impact all the participants in SCs, and would generate long delays and costs - High computing power by BLK uses considerable energy, which is harmful to the environment - BLK consumes energy, which is harmful to the environment. Therefore, research activities should move in this direction to fulfill sustainability principles.	◔
CL	According to (Kodym et al., 2020) [37], the central technology of Logistics 5.0 is CL. CL supports other technologies (Winkelhaus & Grosse, 2020) [39] because it extends IoT possibilities with a more service-based perspective and can dynamically handle a large amount of data generated by IoT. There is no doubt that implementing CL into Logistics 5.0 provides companies with competitive advantages by enabling instant access to stored data without them having to be physically found on company facilities.	- Consolidation and packaging combination - E-commerce - Logistic robotics - Transport costs - Warehouse management - Distribution and delivery	(Evtodieva et al., 2019) [50] state that CL technology positively impacts the sustainability and efficiency of businesses because, by automating or robotizing logistics operations and processes, time is cut and management is carried out in real time.	- Companies are somewhat uncertain about using this technology because they feel they lose control of their information seeing that it is normally an outsourced service - Companies depend on an external provider - If enterprises have no Internet access at a specific time, they cannot access data; these technologies can be vulnerable - Cybersecurity applied to CL in the specific Logistics 5.0 context has been identified as a barrier to be bridged in future research lines [86].	◑
RFID	Most of the analyzed articles mention RFID when listing the technologies to support Logistics 5.0. RFID can also support other technologies like BDA, where RFID provides the data to be analyzed. We, therefore, conclude that the state of applying this technology is quite advanced because we can find real cases of companies employing RFID in Logistics 5.0 with very good results. A number of mobile devices (i.e. barcode and RFID readers, tablets and smartphones) is introduced. In this way, each operator can guarantee the real-time control of logistic processes.	- Delivery points mileage monitoring - Driver and vehicle performance - Fleet vehicles - Fuel use - Geographical localization of in-transport - Inventory count - Order picking - Product traceability	It automates in real time the data related to the logistics operations within different enterprises. Extended RFID use makes this technology appropriate for	- Data transmission - Security - Data management and analysis once data are collected though RFID - Data saving	●
		- Scheduling vehicle maintenance - Storage equipment - Tracking availability or monitoring stock levels - Warehouse management	enterprises` collaboration.		

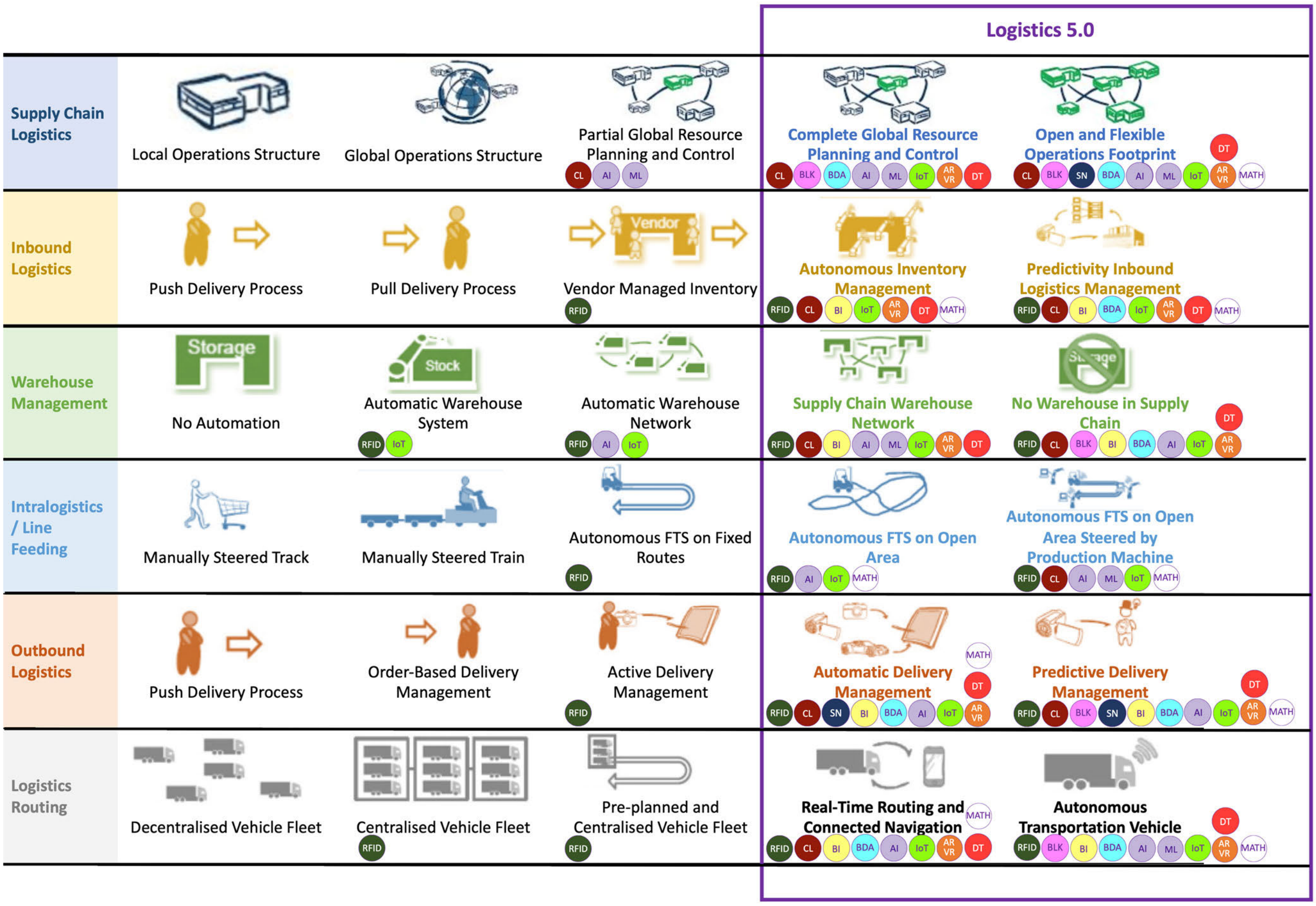


FIGURE 8. Implementation of technologies to support Logistics 5.0 in each logistics component.

process; (iii) the research gaps that can guide future studies in the context of technologies supporting Logistics 5.0; (iv) the status of the application of technologies that support Logistics 5.0 in real cases, where: (i) ○ indicates no real applications found in the literature; (ii) ◔ denotes that real technology applications are in early stages; (iii) ◑ represents how few technology applications are found in the literature; (iv) ◕ symbolizes that different real applications of a technology are found in the literature; (v) ● indicates that the technology has been applied in different sectors during the literature review.

Finally, to combine all the knowledge acquired with the conducted literature review, a graphical classification of the technologies to be applied to each stage of logistics components is proposed to achieve Logistics 5.0 (FIGURE 8). The different logistic components comprise SC logistics, inbound logistics, warehouse management, intralogistics or line feeding, outbound logistics and logistics routing. Each logistic component is also disaggregated by going from less complexity, which involves local decisions and intra-enterprise operations, to higher complexity, which involves SC decisions and inter-enterprise operations [83]

According to Gartner's Framework for Logistics Development, a detailed gap analysis shows that the technology strategy in the Logistics area is underdeveloped. The report also defends the need "*to invest in, deploy and integrate logistics-based technologies (in-house, outsourced or hybrid) that support the day-to-day planning and execution of services across operations*" [95].

The implementation of I4.0 and I5.0 technologies involves changing the functions of human tasks and affects the whole Logistics discipline and associated jobs. According to [75], technological evolution "*creates novel qualification demands and skill sets for employees and, consequently, provide promising directions for IS education*". Research work should focus on the democratization of applying technologies and developing affordable tools so that all types of companies can access them in their businesses.

The work of [60] poses a set of future research challenges in AR technology. However, this work provides a clue about further directions for each technology analyzed in the present paper. The most general ones can be summarized as: (i) investigate advances in I5.0 technologies and their real applications in logistics processes; (ii) empirically

TABLE 6. Research gaps to be covered in future research lines as regards logistics 5.0 technologies.

Tech	Research Gaps in Logistics 5.0	Promising research areas in Logistics 5.0
IoT	- There are no affordable tools that allow high costs to be avoided, especially in SMEs with fewer resources - Human factor knowledge and qualification are limitations for implementing the IoT - The real costs of IoT implementation and returns are unknown	- The development of data service tools will assure data quality, traceability and proper use to implement the IoT - Supply IoT technology and security systems to integrate collaborative logistic processes - Work on the connection of objects and sensors to properly feed the IoT technology to improve not only inbound logistic processes. but also logistic collaborative processes - Apply advanced computing operations to manage and monitor large volumes of real-time logistics data and perform analyses - Define remotely controlled IoT elements of logistic processes to save energy or avoid waiting times - Develop IoT standards to universal and easy-to-use communication networks (examples: NBIoT, LoRaWAN) [87]
AR VR DT	- The relation between product manufacturers and customers by offering added value services with the product monitoring and traceability - AR and VR, which deal with uncertainty in various logistic processes along the SC, are lacking	- Improve the descriptive data definition in the system that will compose AR and VR information systems - Enable virtual validation, visualization and logistics optimization procedures by using previous data and real-time data from different enterprise and SC levels - Deploy supervised classification techniques and time series analyses to replicate different stages of the logistic processes along SCs
DT	- No DT uses for enabling partners to streamline and digitalize the entire logistic process - There are no DT applications to control logistic traceability - The DT that deals with uncertainty in various logistic processes along the SC are lacking - Not knowing the potential use of the DT by logistic actors processes does not make them aware of their effects on process efficiency, sales, being accepted by consumers and their value to gain better insight into consumer behavior [44]	- Develop the DT to analyze the logistic process parameters and diagnose causes in logistic problems in enterprises and SCs - Use the DT to create scenarios for configuring and reconfiguring different logistic processes
CR	- No works appear about the application of CR in Logistics 5.0. Therefore, promising research areas are numerous. We highlight the most relevant ones from the performed research	- Generate synergies among IoT, AI, ML and CR. Make the most of these I5.0 technologies to create CR algorithms. - Use the data corresponding to shipment parameters to optimize routes and directions - Develop routing algorithms based on bioinspired metaheuristics [88] - Develop algorithms based on traffic conditions - Unmanned Aerial Vehicles (UAVs) or drones are the new medium to deliver packages. Their potential lies firmly in the retail, logistics, agriculture and e-commerce fields [89] - Generate regression models to evaluate the battery behavior or autonomous vehicles or cobots [90]
BI	- BI is starting to be used in SMEs, and the managers of these companies are aware that they must employ more sophisticated BI software. Nevertheless, BI software is not affordable - There is still a long way to go to reach the level of large companies, which can invest in both trained personnel and the latest technological updating - There are no signs of BI application in Logistics 5.0 because the authors refer only to production operations - Although managers understand the importance of using BI, which are the areas of improvement in Logistics 5.0 remain unclear - A measurement method is necessary to know the commercial value that BI provides SMEs with	- Spread the use of BI in logistics to gain insights into issues or new opportunities, and ways to improve logistic processes - Implement BI along with transport routes, documentation problems, on-time deliveries, etc. - Create BI applications that deal with business opportunity with potential partners or the new commodities field - Apply BI to improve logistic process decision making by using current and historical data in their business contexts to help logistic companies to run more efficiently [91] - Apply BI technology to deal with large volumes of data that derive from numerous every day operations that involve many SC partners - Develop applications using BI to collect data from different sources and platforms, generate complex reports and deal with automatic information updating - Connect BI with BDA among other technologies to clearly and easily offer a complete vision of the logistic process [92]
BDA	- Tools needed to handle large amounts of data are lacking and the cost of obtaining advanced technology to apply BDA is high - There is no robust financial analysis because this involves confidential business data - More real examples need to appear in the literature	- BDA creates enormous challenges for the organizations that wish to make the most of massive data flows, such as: market trends, customer purchasing patterns, maintenance cycles, and ways to reduce costs and enable more targeted business decisions. - Create systems based on BDA to monitor and predict alerts in logistic processes - Develop services for data integration and fusion to be efficiently processed - Implement BDA services for the characterization and classification of logistics data to support decision making - Model analytic functions and algorithms that support the analytic processes of data scalation - Define procedures for cluster, regression, classification, events detection purposes and the temporary correlation of managed data
AI	- It is an emerging research field that requires many more studies in the Logistics 5.0 area - In the literature, it is very difficult to identify companies' level of maturity in relation to AI implementation, especially in Logistics 5.0	- One of the challenges posed by new technologies applied to Logistics 5.0 is cybersecurity. [69] anticipate that AI can also be used for higher-level processes to detect fraud and to prevent cybersecurity threats in the future - Develop scalable and easy-to-use AI/ML models. - Integration of AI/ML tools with existing systems to deal with insufficient training data
ML	- The application of ML technology is still in an early development stage - There are many gaps related to the competitive advantages offered by this technology, the	

TABLE 6. *(Continued.)* Research gaps to be covered in future research lines as regards logistics 5.0 technologies.

Tech	Research Gaps in Logistics 5.0	Promising research areas in Logistics 5.0
	economic investment required, and whether it is profitable or not to implement it in SMEs - Possessing insufficient training data	
MATH	- Analytical methods are not completely efficient to find suitable solutions for logistic problems. A future research line in the topic under study is to propose heuristic and matheuristic approaches to deal with very complex logistic plans that require handling many models and mathematical approaches, such as algorithms or heuristics. The new era of matheuristics that combines mixed integer linear models with metaheuristics is still in its early development stage.	- Develop models and algorithms to support decision making in logistic networks and processes - Develop models and algorithms to improve collaboration between logistics stakeholders by the collaborative computation of production plans, replenishment plans and delivery plans. - Existing optimization algorithms in the literature should be adapted to take into account the objectives and constraints of all the partners involved in the value chain. New optimization algorithms can be developed to integrate collaborative decision making along the logistics value chain - Negotiation-based algorithms to support the collaborative SC planning process using intelligent modeling and heuristic modeling approaches - Implement data standards to feed algorithms input data - Develop Python optimization algorithms and characterize them through proposing metadata description and input/output configuration - Implement stakeholders' libraries to connect to their legacy systems with algorithms
HI	No works found about applying CR in Logistics 5.0	- Implement hybrid approaches for complex problem solving in the Logistics area - Deploy the hybridization of intelligent techniques to outperform individual computational intelligence techniques - In a hybrid intelligence system, a synergy combination of multiple techniques is used to build an efficient solution to deal with a particular problem [85] - According to [75], HI is a future area of research into logistics to further investigate which kind of governance mechanisms might be applicable in HI systems - Design the best incentive structure for a predefined logistics problem - In production planning, the progress of hybrid approaches application is already being seen [93]
BLK	No studies found that identify the Logistics 5.0 areas that BLK is being applied to	- Develop tools to ensure data trustiness and full traceability - Provide security and trust in the data that flow directly to the BLK to serve as a single point of truth for logistic processes
CL	- CL is a technology that can be vulnerable to common computing risks - Cybersecurity applied to CL in the specific Logistics 5.0 context needs to be addressed	- Implement a cloud service that distributes trust across the cloud architecture - Adjust security and safety policies at different levels to ensure data trustability/privacy - Apply digitization in logistic companies and services with devices acting as sensors that generate data - Apply the real-time management of CL resources by collecting data at any time and looking for the highest quality and the lowest cost of the services offered to users [94]
RFID	Lack of using the information collected by the RFID technology to feed other Logistics 5.0 technologies classified as engineering and data technologies	- Use RFID to access precise data to deal with smart decision making - Deploy human interaction edges to overcome data reprocessing [42]

investigate the viability of applying technologies in different logistics activities; (iii) examine how technologies perform by defining performance indicators and measuring the impact of real-world working scenes; (iv) deal with the efficiency and effectiveness of Logistics 5.0 technologies depending on types of processes, complexity, duration of use and the employed software; (v) study and publish successful implementation knowledge for the successful implementation and diffusion of such I5.0 technologies; (vi) look at how the emerging Logistics 5.0 technologies can be integrated into one another; (vii) this paper investigates the barriers of each technology, but future works should also focus on drivers; (viii) investigate managers and operators' openness for dealing with I5.0 technologies within the logistic processes scope.

V. DISCUSSION

Various dimensions are addressed in the Discussion section, including theoretical implications, practical applications, potential future research avenues and the ramifications of our findings for policymakers.

A. THEORETICAL IMPLICATIONS

Theoretical implications are essential for highlighting the broader impact that the reviewed studies have on the existing theoretical framework and for understanding the Logistics 5.0 subject area. The document offers a general description of the technological solutions highlighted in Logistics 5.0 and their current application status. To answer *RQ1 What technologies potentially support Logistics 5.0?,* extensive research has been carried out on I4.0. This enabled to propose a conceptual model taxonomy based on [9] to classify I4.0 technologies within the Logistics 5.0 scope. Such technologies include the IoT, AR, VR, the DT, CR, BI, BDA, AI-based technologies, ML, MATH, HI, BLK, CL and RFID. The systematic literature review demonstrates that technological developments support one another, mainly the IoT, which is considered the basis for developing Logistics 5.0 and is the backbone that supports the majority of I4.0 technologies, including BI, BDA, BLK, AR, VR or the DT.

This paper concludes by responding *RQ3 What research gaps can be addressed by future research regarding Logistics 5.0 technologies?,* and defines a list of research gaps to be bridged in future research lines with regards the addressed Logistics 5.0 technologies. It highlights promising research domains in the technologies that support Logistics 5.0 by offering a comprehensive view for the research community. While this work was underway, we witnessed the integration of I4.0 and I5.0 technologies by them contributing to the enhanced resilience and sustainability of logistic processes, while also bolstering human decision-making capabilities.

B. PRACTICAL IMPLICATIONS

Discussing practical implications is crucial because it helps readers and researchers to understand the real-world applications and consequences of the reviewed studies. In this regard, *RQ2. What is the status of applying these technologies in real cases?,* is answered in Table 5 by highlighting the application status of the Industry 4.0 and 5.0 technologies to support Logistics 5.0 in real cases. Most applied technologies in the Logistics 5.0 context are the IoT, BDA and RFID. According to the reviewed literature, MATH approaches and CL technologies are more applied in enterprises, which demonstrates that affordable tools are being developed in these areas. Nevertheless, the application approaches of Logistics 5.0 technologies in real enterprises and SCs are necessary in other analyzed technologies, such as AR, VR, the DT, BI, ML, HI and BLK.

C. POLICYMAKERS' IMPLICATIONS

Policymakers play a key role in the digitization of the logistics sector to take the Logistics 5.0 concept closer to industries in several ways by: (i) establishing and enforcing standards for data exchange, communication protocols and technology interfaces; (ii) considering issues like security, privacy and interoperability among IoT services; (iii) influencing the accessibility and affordability of I4.0 and I5.0 technologies; (iv) engaging in international collaborations to establish global standards for communication networks; (v) developing and upgrading the necessary digital infrastructure for Logistics 5.0, including intelligent transportation systems and real-time data analytics, to facilitate efficient logistics operations; (vi) contributing to the development of smart cities and physical infrastructures, which are integral to Logistics 5.0; (vii) implementing training programs to enhance the digital literacy of the workforce in the logistics sector; (viii) collaborating with education institutions to align curricula with the logistics industry's evolving needs by creating a workforce that is ready to embrace digitization; (ix) negotiating trade agreements that promote the free flow of goods and information by encouraging the adoption of digital technologies in logistics on a global scale.

D. FUTURE RESEARCH LINES

The systematic literature review allows the authors to highlight the following future research lines that derive from the gaps outlined in Table 6: (i) enterprise managers understand the importance of using technologies to support logistics; nevertheless, the papers reviewed to date do not specifically emphasize the areas of improvement in which SMEs apply such technologies to achieve Logistics 5.0; (ii) acquiring more in-depth knowledge about the factors that influence the adoption of Logistics 5.0 technologies in industrial organizations is crucial; (iii) a measurement method is necessary to know the commercial value that Logistics 5.0 technologies provide SMEs with and the competitive advantages offered by Logistics 5.0 technologies, the required economic investment and whether it would be profitable to implement it in SMEs; (iv) cybersecurity applied to Logistics 5.0 technologies has been identified as a gap to be bridged in future research lines; (v) a general gap appears because the current literature does not present real examples. So further literature on the application approaches of Logistics 5.0 technologies in real enterprises and SCs is necessary; (vi) no research works appear about Logistics 5.0 with CR and HI that employ metaheuristics and matheuristics. Hence a future research line in this direction can be initiated; (vii) consider the added value of services for aftermarket Logistics 5.0; (viii) identify to what extent implementing the emerging technologies applied to Logistics 5.0 affects loss of jobs. This is considered a promising research line; (ix) technologies aligned with human values to work collaboratively with logistic employees rather than replacing them, and help in decision-making processes with a hybrid combination of human and artificial intelligence.

VI. CONCLUSION

For Industry 5.0 to exist, there must be a synergy with the development of Logistics 5.0. In this paper, a systematic literature review on the technologies that support Logistics 5.0 has been performed. All the reviewed technologies announce a turning point at which the physical and digital worlds can be managed as one, and enterprises and humans can interact with the digital counterpart of physical things similarly to the way we would with things themselves, and even in the 3D space around us. It should be noted that this literature review has some limitations. The authors consider that the Scopus database and research works are continuously included, especially in novel terms referring to new I5.0 in different areas. The reviewed literature goes up to January 2021, but several works in the research area of technologies that support Logistics 5.0 have been published, which confirms the increasing significance of this discipline. Furthermore, although a systematic literature review has been conducted, this work may not have addressed additional meaningful works and could include more works with business perspective publications. Regardless of the identified limitations, these can be seen as research opportunities to be addressed in future works.

The research throughout enabling technologies for Logistics 5.0 has approached relevant theoretical insights, practical implications and future research lines to address the contemporary challenges faced by the logistics sector. Digital solutions, based on I4.0 and I5.0, are analyzed and evaluated to promote affordable implementations in the sector. The application of Logistics 5.0 principles will enhance efficiency, reduce costs, improve customer experiences and contribute to environmental sustainability, which are essential for companies to remain competitive and resilient in an ever-evolving global supply chain landscape.

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BEATRIZ ANDRES received the master's degree in advanced engineering in production, logistics and supply chain from Universitat Politècnica de València (UPV), Spain, and the Ph.D. degree in enterprise engineering and production from UPV, funded by Programa VALi+d per a Investigadors en Formació from the Valencian Government, in 2016. She is currently an Associate Professor in operations management and operations research with UPV, where she is also a member of the Research Centre on Production Management and Engineering (CIGIP). She has participated in several Spanish Government and European Research and Development Projects. Her current research interests include the areas of collaborative networks, strategies alignment, decision support systems, and non hierarchical manufacturing networks. She is a member of the Socolnet Society, a community of researchers and professionals in collaborative networks. She has published several research papers in international conferences and indexed journals.

MANUEL DIAZ-MADROÑERO is currently an Associate Professor with the Department of Business Management, Universitat Politècnica de València (UPV), Spain. He teaches subjects related to information systems, operational research, and operations management and logistics. He is a member of the Research Centre on Production Management and Engineering (CIGIP), UPV. He has participated in different research projects funded by the European Commission, the Spanish Government, the Valencian Regional Government, and UPV. As a result, he has published (in collaboration) more than 40 articles in different indexed journals and international conferences. He is the coauthor of the book *Operations Research Problems: Statements and Solutions* (Springer, 2014). His research interests include production planning and transportation, fuzzy mathematical programming and robust optimization, multicriteria decision making, and sustainable operations management.

ANTONIO LUCAS SOARES is currently an Associate Professor with the Department of Informatics Engineering, Faculty of Engineering, University of Porto, and a Researcher with INESC TEC. His area of expertise is information systems specialized in applications to collaborative networks and information and knowledge management, particularly in industrial organizations. His research interests include socio-technical design, knowledge representation, digital platforms for collaboration, and design science research. He teaches information systems analysis, requirements engineering, information management, and research methods. He is also coordinating the Center for Enterprise Systems Engineering, INESC TEC.

RAUL POLER received the Ph.D. degree in industrial engineering, in 1998. He is currently a Professor in operations management and operations research with Universitat Politècnica de Valencia (UPV), Spain. He is also the Director of the Research Centre on Production Management and Engineering (CIGIP). He has led several Spanish Government and European research and development projects. He has published 100 of research papers in a number of leading journals and international conferences. He is a Representative of INTERVAL (the Spanish Pole of the INTEROP-VLab). He is a member of the Association for the Organization Engineering (ADINGOR), the IFIP WG 5.8 Enterprise Interoperability. His research interests include enterprise modeling, decision support systems, collaborative networks, knowledge management, production planning and control, and supply chain management.