IEEE Access
Multidisciplinary ⁝ Rapid Review ⁝ Open Access Journal

Received May 20, 2022, accepted May 31, 2022, date of publication June 8, 2022, date of current version June 15, 2022.

Digital Object Identifier 10.1109/ACCESS.2022.3181154

Supply Chain Management, Game-Changing Technologies, and Physical Internet: A Systematic Meta-Review of Literature

DAVID L. CORTÉS-MURCIA, WILLIAM J. GUERRERO, AND JAIRO R. MONTOYA-TORRES
Research Group in Logistics Systems, School of Engineering, Universidad de la Sabana, Chía, Cundinamarca 250001, Colombia

Corresponding author: David L. Cortés-Murcia (david.cortes@chiper.co)

This project has received funding under the Horizon 2020 Framework Programme of the European Union - Grant Agreement No. 861584, and Universidad de La Sabana, Colombia - Grant Agreement INGPHD-39-2020.

ABSTRACT To improve the effectiveness and the sustainability of logistics, the Physical Internet paradigm proposes disruptive solutions. This implies developing an ecosystem of tech-based logistics solutions and supporting methodologies that enable all players in global trade to cooperate. The purpose of this paper is to investigate systematic literature review (SLR) studies to gain detailed insight into how innovative transport technologies, and digitalization initiatives around the Physical Internet development impact supply chains. This paper presents the results of a tertiary study that systematically identified more than twelve thousand articles and selects to review 74 secondary studies on the application of disruptive technologies and the Physical Internet initiative on supply chains from a management perspective. This is complementary to previous reviews, since no one provides a comprehensive and consolidated approach towards the relationship of these three fields. The five-stage systematic review process proposed by Denyer and Tranfield (2009) is followed. As a result, we identify the key activities, knowledge areas and strategies in the supply chain field where the Physical Internet and disruptive technologies interact and are game-changing. Also, we present a conceptual framework that summarises the relationships that exist between relevant disruptive technologies, the physical internet topics, and supply chain key activities. The framework is helpful for researchers and practitioners to find potential technologies to invest in, to assess the potential effects on companies of their implementation, and to support strategic decision-making. The paper concludes with an outlook on future research opportunities from operational, tactical, and strategic perspectives.

INDEX TERMS Disruptive technologies, logistics, physical internet, supply chain management, systematic literature review, tertiary study, transport.

I. INTRODUCTION

Since the Kyoto Protocol, governments and policymakers around the world have tried to deal with the increasing environmental challenges resulting from the climate crisis, pollution, and deforestation that endanger the sustainability of the planet [1]. However, in recent years, mankind proved that reducing the negative impact of supply chain (SC) operations on society and the environment is a difficult task [2]. Additionally, the United Nations proposed an agenda for 2030 composed of a set of 17 Sustainable Development Goals (SDG), which includes efforts to ''make cities and human settlements inclusive, safe, resilient and sustainable'' (SDG 11), ''ensure sustainable consumption and production patterns'' (SDG 12), and ''take urgent action to combat climate change and its impacts'' (SDG 13).

Transport is a key driver in many economic activities that account for about 24% of world CO_2 emissions [3]. Moreover, the accelerating technological changes and the establishment of new players in international trade force local, regional, and global transportation to change. Due to this, there is an increasing interest in developing research around topics such as reverse logistics, closed-loop logistics, green logistics and environmental logistics [4]. Also, there are projects with international cooperation and with multidisciplinary research groups from universities and companies

The associate editor coordinating the review of this manuscript and approving it for publication was Mauro Gaggero.

developing disruptive and environment-friendly technologies as well as new policies for Supply Chain Management (SCM) in a global context.

On the other hand, as part of the arising of the fourth industrial revolution, the digital revolution is characterized by the convergence of technologies that is blurring the lines between physical and digital worlds. Also, the mix of very different technologies disrupt current and future systems. For example, blockchain has the distributed peer-to-peer nature that can address the weaknesses and vulnerabilities of internet of things in terms of security, reliability and computational effort efficiency [5].

Due to this revolution, the concerns from the supply chain management perspective nowadays include the development of projects that look for developing an interoperable ecosystem of tech-based logistics solutions and for supporting methodologies. It is expected that these solutions enable all players in global trade to co-operate and to react in an agile way to volatile political context, market changes, and climate shifts impacting traditional trades. These projects are looking to speed up the path of the Physical Internet (PI). PI is a game-changing concept in the SCM field that implies the development and combination of technologies to create a collaborative logistic network and face the issues that make the current logistics practices unsustainable [6].

A disruptive technological development is also associated with the concepts of Industry 4.0. Further, according to [7], in Industry 4.0 three aspects can be distinguished: a paradigmatic one, a technological one, and one related to sustainability. Even if these three aspects are also remarkable in the PI, the PI topic is rarely mentioned in Industry 4.0. literature.

Several PI literature reviews provide strategies to classify the literature on the PI, present research opportunities, or outline the main PI themes, facilitators and barriers [8]–[11]. Despite this, no review provides a comprehensive and consolidated approach towards the relationship of disruptive technologies, the PI themes and SCM activities. While the common elements of these concepts have been examined, there is still a gap in the literature on understanding the evidence on how SCM activities are positively impacted by applying each of the leading Physical internet components and technologies within a common framework. The latter is the main motivation of this paper. We consider that the understanding of the relations between the physical internet, the supply chain management activities and the disruptive technologies will bring an overview for practitioners to improve decision-making during under the transformation promoted by the fourth industrial revolution.

Thus, the purpose of this paper is to analyse the evidence and gain concrete insight into how disruptive technologies (e.g. main innovative transport technologies, state-of-the-art tools, technological solutions, and digitalization initiatives), and the physical internet initiative are impacting the supply chain management. The research question (RQ) stated in this paper is:

RQ. How are the key activities, knowledge areas and strategies in SCM impacted by the development of PI and disruptive technologies?

The RQ encompasses a wide variety of research fields, as well as a multidisciplinary approach. Performing a comprehensive review of the entire (primary) literature on these fields would be a project too ambitious to accomplish. However, we can synthesise research in these areas by reviewing existing systematic literature reviews (SLRs). This allows us the identification of research streams, whose analysis and synthesis help to answer the RQ. In this line of thought, this paper presents the results of a tertiary study, a meta-review, of already existing SLRs. An SLR is proposed as the methodology to answer the RQ because it is a replicable, scientific, and transparent approach, which seeks to minimize bias [12].

The originality of this paper is twofold:

- From what we can tell, there is no other tertiary study looking to consolidate the relationship of disruptive technologies, the PI themes and SCM activities.
- We present a conceptual framework that extends the framework proposed by [10]. This framework summarises the findings and shows which knowledge areas and strategies in the SC are affected by the joint development of disruptive technologies and the PI.

This framework is compelling for academics and practitioners in the engineering management field because there is a persisting need to investigate emerging trends as a mitigation strategy against the risk of losing value due to external market disruptions. In fact, the average organization spends about $220,000 of its annual budget to do so [13]. Also, this framework helps readers to gain insights into the PI topic that did not receive much attention in either the Industry 4.0 or SCM literature, so far.

The structure of the paper is as follows: The research background of key topics for the development of this study is provided in Section II. Section III presents the methodology for the systematic literature review employed in this study. Based on the results, Section IV shows a conceptual framework illustrating the interaction between PI themes, disruptive technologies and knowledge areas and strategies in SC. Section V shows the research results addressing the research questions, and the implications for academics and practitioners. Finally, Section VI outlines the conclusions of the study, limitations, and future research.

II. RESEARCH BACKGROUND

This section provides a research background about PI, and disruptive technologies. So, the reader has a unified definition of the key concepts used in this paper.

A. PHYSICAL INTERNET

The Physical Internet (PI or π) is a concept conceived at the beginning of the 2010s. This initiative aims to respond to the inefficiencies and non-sustainability of current logistics and SCM practices [6]. The PI is expected to work by organizing transportation of physical goods as data packages are moved on the digital Internet [10]. Ballot [14] describes PI as the application of the Digital Internet principles to logistics networks, while [15] defines it as an SC framework that is based on a network of physical components.

Physical components are expected to exchange information to improve the effectiveness, efficiency, and sustainability of SCM operations [15]. Montreuil *et al.* [16] state that the physical elements that make the PI are π-nodes, π-movers and π-containers. These elements rest on the principles of universal interconnectivity, encapsulation, standard smart interfaces, standard coordination protocols, logistics web enablers, and open logistics systems [17]. The π-containers are conceived as the unit loads that are manipulated, routed by π-movers, and stored in π-nodes.

Due to its novelty, it is still early to perform an analysis of the PI adoption. However, the PI is rapidly gaining relevance in both academic and practitioner circles [10], [11]. This is because there are groups of people and organizations developing and supporting the vision of the PI. The Alliance for Logistics Innovation through Collaboration in Europe (ALICE) is set up to develop a comprehensive strategy for research, innovation and market deployment of logistics and supply chain management innovation in Europe. This group already proposed a roadmap of how the PI will gradually replace the logistics of today [18].

B. DISRUPTIVE TECHNOLOGIES

One of the key enablers of PI or Industry 4.0 is the technologies that allow all players in the value chain to be digitally connected. According to [19], these disruptive technologies not only have the potential to drive fundamental shifts in society, but they also enable simpler and more cost-effective business operations, decision-making and production processes. In the following, the main technologies considered in the further sections of this paper are described.

1) BLOCKCHAIN

Blockchains are ledgers that record transactions in a trustless environment and are protected by the science of cryptography. The blockchain works as a network of nodes, meaning that each node has the same chain decentralized to its database [20]. One relevant advantage of this technology is that there is no need for a third party to verify the transactions because this verification is decentralized and performed by the nodes (clients) connected to each block. Some additional features of blockchains are that they are immutable, transparent and secure [21].

2) CLOUD COMPUTING (CC)

In cloud computing, a pool of configurable computational resources is in virtualized and distributed environments, usually, geographically disperse. The shared resources include data storage, processing power, databases, networks, on-demand environment for developing, virtualization, and software applications. These can be rapidly provisioned and released, with minimal management effort, on an on-demand basis through web-based technologies [22]. Clouds are data and information hubs, providing infrastructure, platform, or software services [7]. Thus, in a potential application in SC and logistics, such platforms receive data from the ubiquitous sensors and analyse and interpret the data for providing users with an easy-to-understand web-based visualization [23]. From this technology, new business models appear, which will be described in section IV-C3.

3) CYBER-PHYSICAL SYSTEMS (CPS)

A CPS is formed by the integration of computation, networking, and physical processes. It implies signal processing and control of manufacturing processes using computers [23]. So, the CPS uses the information to directly act in the physical world, usually with feedback loops where physical processes affect computations and vice versa [7].

4) INTERNET OF THINGS (IoT)

The IoT enables the information generation and transmission from objects into a IT system. It means that IoT can provide smartness to objects by the interconnection of sensing and actuating devices, like the Radio Frequency Identification (RFID) technology [7]. Therefore, the IoT can connect individually identified products, machines and people together to provide optimized solutions, through data storage, analysis equipment and decision-making tools [24].

5) BIG DATA ANALYTICS (BDA)

BDA seeks to produce (from large amounts of data) useful insights or products and services of significant value to executives at different levels, enabling them to develop better decision-making processes [24], [25]. Big data are extensive data sets characterized by the five V's: volume, variety, velocity, veracity, and value. Thus, BDA provides tools to manipulate and process large data sets [7], [24].

6) ARTIFICIAL INTELLIGENCE (AI)

AI purpose is to imitate the human brain and perform decision-making like human beings under various situations and circumstances [26]. Machine learning (Deep Learning and Predictive Analytics are often described as applications of Machine learning), Natural Language Processing and Image Recognition are relevant applications of AI.

7) AUTONOMOUS VEHICLES

Driverless or fully autonomous vehicles are vehicles that are sufficiently automated that the driver can safely engage in other activities, or that can drive themselves without a human driver. It is a reality on certain transport legs due to the technological revolution in areas such as AI. For road transport, autonomous cars are being developed and tested (e.g. T-pods), while for air-based transport, unmanned aerial vehicles or drones are also being introduced for delivery services [27]. This paper mentions applications and uses of autonomous vehicles with an autonomy level greater or equal to level 2: ''On- and off-board decision support'' proposed by [28].

III. METHODOLOGY

To address the research question (RQ), the Systematic Literature Review technique is used. We decided to conduct a systematic literature review rather than a narrative review because the latter do not have common frameworks to ensure reproducibility of the studies. Since the objective is to gather and synthesise the literature located, a meta-analysis or a bibliometric review were not considered. Moreover, performing a comprehensive review of the primary literature on the proposed fields would be a project too ambitious to accomplish. So given that we have we found enough SLRs (secondary sources) we perform a tertiary study framed in a Systematic Literature Review scheme. The SLR is defined as a well-established procedure that synthesises research in a systematic, transparent, and reproducible manner. This method provides an auditable trail of the reviewers' decisions, procedures, and conclusions [29]. In this paper, information from different academic documents dedicated to a variety of domains and topics (i.e., disruptive technologies, Industry 4.0, PI) is integrated.

The five-stage systematic review process proposed by [12] is followed. These stages are: (i) formulation of the research question, (ii) locating studies, (iii) study selection and evaluation, (iv) analysis and synthesis, and (v) reporting and using the results. Figure 1 describes each of these stages, which are explained below.

A. RESEARCH QUESTION

The general research question (RQ) reflexes the scope, purpose and goals to look for in the SLR. The RQ is:

RQ. What are the current and new key activities, knowledge areas and strategies in the SC field where the PI and disruptive technologies are game-changing?

Since the purpose of the paper is to illustrate the relationships between three different domains of knowledge (technologies, MTS and IP), this general research question is broken down into the following specific questions. The latter were designed to identify elements and relationships between pairs of concepts and by transitivity find a common framework to answer RQ.

RQ1. What are the main disruptive technologies and global initiatives impacting international multimodal freight movement and global transport networks?

RQ2. What are the key activities, knowledge areas and strategies in SCM where the PI and disruptive technologies are game-changing?

RQ3. What are the main applications of the disruptive technologies in favour of the SCM?

RQ4. How are the main applications of emerging disruptive technologies and existing tech solutions in SCM related to PI elements?

TABLE 1. Strings of search terms used in the systematic literature review.

String search ID	Keywords
[#1]	"intermodal freight transport" OR "physical internet"
[#2]	"logistics" OR "International cooperation" OR "Multimodality" OR "supply chain" OR "shipping"
[#3]	"intermodal logistics" OR "synchromodality" OR "silk road" OR ("belt" AND "road initiative") OR "hyperloop" OR "autonomous vehicles" OR "artificial intelligence" OR "Industry 4.0" OR "Transport networks" OR "internet of things" OR "big data" OR "blockchain"
[#4]	"systematic literature review" OR "systematic review"

B. LOCATING STUDIES

Relevant studies were identified by conducting a database search. Three well-known databases are considered: Emerald Insight, Scopus, and Web of Science. They are selected for two reasons. Firstly, these databases provide access to high-quality research literature in relevant domains, as well as to a large number of publications and peer-reviewed articles. Secondly, their search engines allow performing queries with long string search chains. Because of the latter, ScienceDirect database or Google Scholar search engine are not considered. Further, selecting more than one database reduces the risk of research biases. The list of key search terms is created based on the pilot review and are presented in Table 1. In the string [#1] we include ''intermodal freight transport'' because these studies are highly related to the Physical Internet Paradigm, the contributions to this field can be extended to the PI, and it has been studied before the PI definition. The search is conducted between September 20th and October 5th, 2021. The search field is restricted to ''Title-Abstract-Keywords''. Logical and boolean operators are used to build the string search chain ([#1] OR ([#2] AND [#3])) AND [#4]. Additionally, papers are selected without restriction on publication year. The output of this search step is a comprehensive list of documents for each database that could help to answer the RQs.

C. STUDY SELECTION AND EVALUATION

The choice of documents is done fitting to an explicit selection criterion. According to the type of published document, only journal papers, review papers and book chapters are included. Papers that apply a Systematic Review are included. Only papers published in English are selected, as English is the dominant language in the field of engineering management. A selection based on the relevance in terms of intermodal freight transport is done by analysing their title, abstract and keywords. Thus, documents dedicated to a particular SC (i.e., health care or agriculture), or documents with no thematic or content analysis are discarded. Also, reviews of disruptive technologies which do not present a relevant discussion on the impact or application in the fields of SC

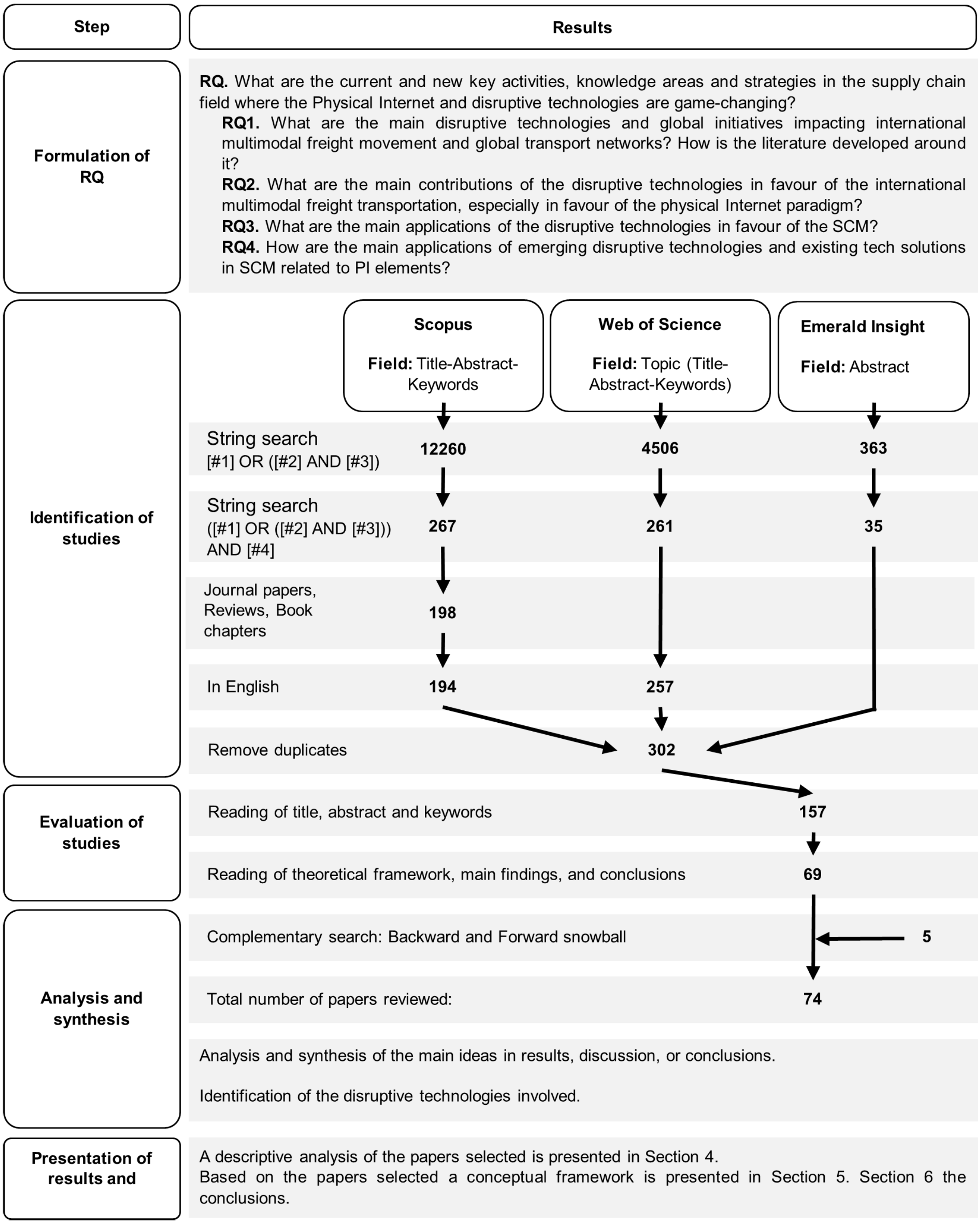

FIGURE 1. Summary of the systematic literature review methodology.

or transport are not included. These selection criteria are applied to ensure the transparent choice and that the selected papers are focused on the topic under investigation. As a result of this selection, the number of documents is reduced to 157.

D. ANALYSIS AND SYNTHESIS OF THE RESULTS

In this step, the selected articles are analysed by reading them in their entirety. During the analysis, from each review, the disruptive technologies mentioned and their relations with SCM are captured. A database is designed in a spreadsheet containing the research questions, a taxonomy based on the technologies mentioned, and contributions of each document. Complementary information as title, author, journal, year of publications, the number of reviewed documents and its publication time windows, are also identified. After this step, 69 documents remained on the list of significant contributions.

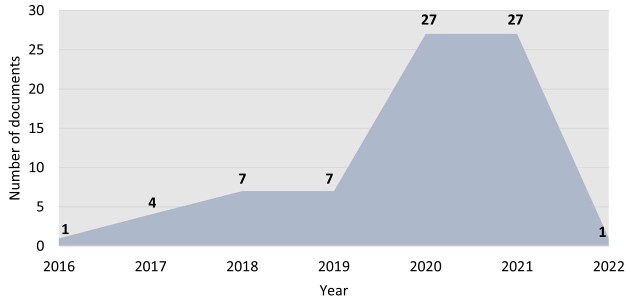

FIGURE 2. Evolution of scientific production over time.

Lastly, forward and backward searches are done to ensure a full and exhaustive literature review. Five reviews are identified employing the snowballing effect. Thus, 74 articles are identified that satisfied the selection criteria and, consequently, are relevant to answer the proposed research questions.

E. PRESENTATION OF RESULTS AND CONCLUSIONS

In this section, a descriptive analysis of the reviewed documents is presented. Part of the results presented below are obtained by using the Bibliometrix R-tool [30]. First, the evolution over the time of the short-listed papers published is presented in 2. The oldest selected document date from 2016 and the number of publications is increasing year to year, showing the relevance of the PI, disruptive technologies, and SCM fields.

There is a wide-spread contribution of articles over diverse journals. Table 2 shows that 13 journals have published 2 or more papers (cumulating 71.62% of papers). International Journal of Production Research (10 papers), Sustainability (Switzerland) (9 papers) and Supply Chain Management: An International Journal (6 papers) are the most contributing journals. Two of these three journals stand out in the fields of Operations Research, Operations Management and Supply Chain Management for the number of papers published and their cite scores. The other journals have different scopes, being sustainability, information technology or logistics. This emphasises the interdisciplinary character of this study.

Figure 3 shows the classification by the country related to the affiliation of the corresponding author of each document. The figure summarizes the countries that have published at least two articles, no matter if it is a single country or multiple country publication. The United Kingdom and Austria are the most contributing countries with 7 documents each.

In addition, we read the shortlisted articles and the results are summarized in a conceptual framework presented in Section IV. This framework answers the RQs. Also, a discussion of the findings and the identification of research gaps and future research lines are presented. In addition, in the Appendix., we present the comprehensive list of documents selected and a resume of the taxonomy.

TABLE 2. Classification by journals.

	Number of papers	Share
International Journal of Production Research	10	13.51%
Sustainability (Switzerland)	9	12.16%
Supply Chain Management	6	8.11%
Benchmarking	5	6.76%
IEEE Access	4	5.41%
International Journal of Logistics Research and Applications	4	5.41%
Production Planning and Control	3	4.05%
Computers and Industrial Engineering	2	2.70%
International Journal of Logistics Management	2	2.70%
International Journal of Physical Distribution and Logistics Management	2	2.70%
Journal of Manufacturing Technology Management	2	2.70%
Operations and Supply Chain Management	2	2.70%
Transport Reviews	2	2.70%
Others (Journals with one paper)	21	28.38%
Total	74	100.00%

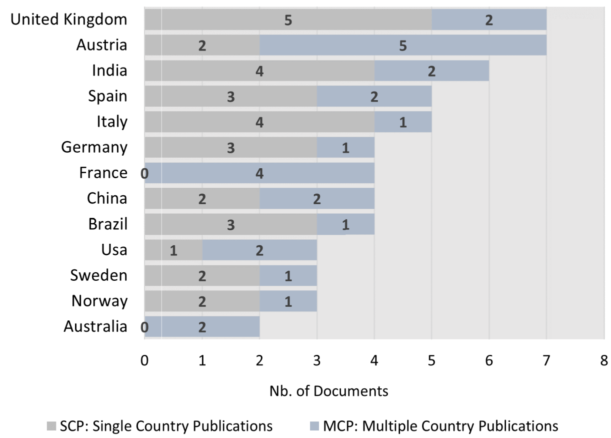

FIGURE 3. Classification by journals.

IV. CONCEPTUAL FRAMEWORK

The results obtained by applying the SLR are summarized through the elaboration of a conceptual framework, which is introduced in this section. This framework provides answers to RQ1-RQ4. The framework shows graphically how is the interaction of knowledge areas and strategies (KAS) in the SC with the PI and the relevant disruptive technologies. This, by positioning each KAS on a grid where the rows are components of the PI, and columns present the disruptive technologies.

First, the main PI themes are selected from the PI-Based framework presented by [10]. Thus, KAS in SC can be classified according to its relationship with the following seven PI themes: Modular containers, Vehicle usage utilization, Transit Centres (hubs), Data exchange (seamless, secure, and confidential data exchange), Legal framework, Cooperation Models, and Business models. This classification not only involves the PI components (see Section 2), but also allows the reader to identify the KAS from an operational decision level (Modular containers) to a strategical decision level (Cooperation Models, and Business models).

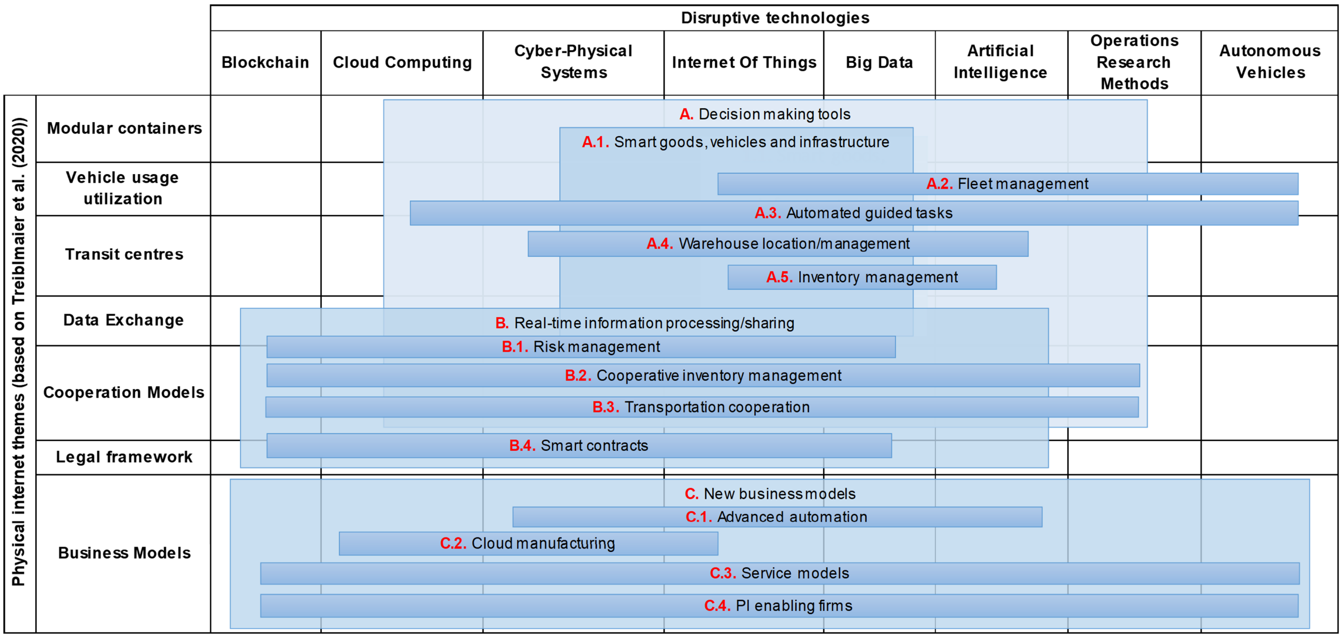

FIGURE 4. **Conceptual framework diagram.**

Based on the taxonomy results of our SLR (see Appendix.), the most mentioned disruptive technologies are selected, namely Blockchain, Cloud Computing, Cyber-Physical Systems, Internet of Things, Big Data, Artificial Intelligence, Operations Research Methods and Autonomous Vehicles.

It is important to mention that Big Data, Artificial Intelligence, and Operations Research Methods are parts within the analytics field. Data analytics techniques are classified into descriptive, predictive and prescriptive analytics [31]–[33]. Descriptive analytics is considered the most basic approach to analytics and is based truly on the principle of classical statistics methods [31]. Predictive analytics involve data mining, machine learning and more advanced statistics to identify patterns in data and convert them into business rules [34]. Prescriptive analytics is used to propose sets of actions based on past events. Prescriptive analytics is mainly associated with optimisation and simulation (named as operations research methods in the conceptual framework), and has special relevance in contexts of uncertainty [34].

Despite the relevance of analytics in the literature, we consider that an exhaustive study of the relationship between the analytics field and SCM is beyond the scope of this paper. Readers interested in frameworks that relate how data analytics shapes SC processes can refer to [35]–[37]. However, since our taxonomy results shows the relevance of Big Data, Artificial Intelligence, and Operations Research methods, we mention them in our framework as technologies in order to show the importance that the reviewed papers give to these specific technologies.

In addition, if any other technology has a relevant application, it is mentioned in the framework description (i.e., Augmented Reality, additive manufacturing or the Road and Belt Initiative). Finally, the KAS are identified as a result of the SLR. In the following, a description of the selected KAS and its links with PI themes and disruptive technologies is presented. Figure 4 shows the conceptual framework diagram.

A. DECISION-MAKING TOOLS

In the engineering management context, decision-making is challenging due to the complexity, dynamism, and uncertainty of the environment. For instance, inaccurate demand forecast and a lack of shared information between chain members can lead to the bullwhip effect, unnecessary logistics costs and increased delivery times [38]. Similarly, in transportation, there are significant complexities due to a large number of delivery points, variable demands, or changing travel conditions which are difficult to manage in practice. Also, PI modular containers need to be designed to optimize their use, to efficiently and effectively use cargo handling in transit centres and hubs [10].

Decision-making tools in the SC rely on Operations Research and Management Sciences. Operations Research Methods form a part of the concept of a smart factory and are useful to adopt optimal operations planning which lead to production flexibility and enhanced innovations [23]. These tools are also used in scenarios where optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives [39]. Operations Research Methods include mathematical programming, simulation, metaheuristics, queueing theory, multiple-criteria decision making and system dynamics [40]–[43]. In addition, the other disruptive technologies provide insights to improve current

Operations Research methods. Also, these generate valuable information for forecasting and planning future actions and behaviours [17].

Concerning data capturing and data processing, the usage of CPSs and IoT can allow companies to get automatic and real-time data from different points throughout the SC [44]. Also, Cloud-Based Systems can provide high storage capacity and high-speed computing, enabling quick and independent access to data from any location [22]. This capability can provide significant support for decision-making and planning and can result in dramatic improvements in real-time problem-solving and cost avoidance [7], [45].

To take advantage of this data, BDA enable companies to have real-time focus and simultaneous analysis of multiple data streams. BDA gives to the organizations the ability to use tools and techniques to analyse SC data in batch-wise, real-time, near-time, or as it flows and extracts meaningful insights for decision-making [31]. Also, BDA methods have the potential to ease communication between automation systems. Thus, the decision-making process can be automated or semi-automated [38], [46].

Given the volume of information, Artificial Intelligence (AI), and particularly Machine Learning (ML), can provide solutions in integrated production management [47], predict the probable backorder products before actual sales take place [48]. Also, it can be used in optimisation, automation, and human support by handling complex problems [49]–[51]. Woschank *et al.* [52] argue that decision-relevant information would be automatically collected, aggregated, and pre-analysed by AI, ML, and Deep Learning technologies. Also, Woschank *et al.* [52] show that these hybrid decision-making processes outperform purely rational decision-making processes.

According to Gupta *et al.* [50], Operations Research Methods has the ability to identify and provide optimal solutions in a well-defined problem space. Therefore, the challenge lies in providing illustrations that have sufficient expressive power for real-world scenarios and can promise fast and precise solution, and an AI and Operations research methods integration is promising to overcome these challenges. This integration can be applied to different areas of operations, i.e. routing, scheduling, pricing, process forecasting and control, among others. These fields can be supported with the help of AI techniques ranging from case-based reasoning, fuzzy logic, knowledge-based systems, genetic algorithms, and hybrid techniques [50]. Also, techniques for pattern recognition and operations research methods have to be combined more often to adequately incorporate disturbances and changing parameter values into operational, tactical, and strategic decision-making simultaneously [46].

In the reviewed documents we found case studies showing how the implementation of disruptive technologies can improve the Operations Research Methods and, therefore, decision-making task in: waste management, water supply networks, power plants [53], food SC [54], resource allocation [55], supply chain network design [39], scheduling, purchasing, procurement, physical distribution [46], traffic information analysis in real-time [38], [53], [56], route planning and refuelling, pricing negotiations, maintenance times and packages flow optimisation [53], [55], [57], [58]; maritime logistics chain optimisation, fleet optimisation [59], truck arrival time prediction, blood SC [31], forecasting demand [43], [56], [60], product development [34], virtual design and simulation of processes [19], [59], [61]; predictive maintenance, human-expert-driven decision-making and AI-driven decision-making approaches for smart manufacturing processes based on AI and ML [52].

In general, integrating external data lead to real-time enabled response modelling and would provide the necessary data for more holistic and realistic models. In this way, Smart goods, vehicles, and infrastructure are keys enablers. In the proposed framework, decision-making tools are embedded in fleet management, automated guided tasks, warehouse location/management and inventory management. Also, these play a key role in real-time information processing and cooperation strategies.

1) SMART GOODS, VEHICLES AND INFRASTRUCTURE

Data is scattered, and diverse sources can provide it. Usually, the primary data sources are Enterprise Information Systems, Enterprise Resource Planning systems and inter-organisational systems. Besides, IoT devices, sensors, and RFID devices can collect data and feeding it to information systems, which in turn generate a huge volume of unstructured data [31], [34], [62].

This embedded cyber-physical intelligence and IoT technologies can be applied in SCM to enhance visibility through enabling monitoring and tracking capabilities. In particular, the combined use of RFID technology, BDA, Blockchain and cloud-based systems can empower real-time traceability of goods and interoperability of resources, leading to improved planning and controlling throughout the SC [38], [44], [62]–[64]. Also, IoT-assisted data-driven digital twins can be integrated with reinforced learning platforms to assist truck route optimisation, automated warehouse storage and retrieval systems, decentralized scheduling, risk management, intelligent transportation system, and other micro and macro reverse logistics procedures [49], [65]. These operations research methods can be used in real time via a cloud computing platform [17], [22], [23].

Real-time traceability has more benefits than just improving the visibility of goods at the data level [7], [41], [63], [64], [66]. Better visibility and information accessibility can reveal opportunities to minimize lead times in warehouse and transportation tasks, to improving manufacturing flexibility, product quality, energy efficiency, and to improve equipment service and communications with customers, leading to a reduction in costs and increases in efficiencies [67].

Recent literature reveals a tendency towards the design and activeness of the PI modular containers, with an emphasis on data sharing connectivity structures and visibility improvements. Using smart tags, including RFID and GPS technologies, PI modular containers collect and store logistics and SC information. In addition, modularisation, multi-functional load units and advanced encapsulation processes are studied as alternatives to increase the fill rate [17]. The activeness of PI modular containers results in better grouping strategies and real-time optimisation to decrease empty containers via cloud computing.

However, all these benefits entail challenges related to information security, new regulation requirements, complex network implementation, high implementation costs, hardware and software issues, standardisation and data handling [7], [68]. Also, others risks as low data quality, distrust and trust management, economic risk or complex network coordination can emerge [68].

2) FLEET MANAGEMENT

Performance of transport logistics can be increased by applying AI-based methods in combination with state-of-the-art approaches based on the usage of information technology, data communication technology, electronic sensing technology, global positioning technology, geographical information system technology, real-time road status, navigation, computer processing technology, and system engineering technology [38], [52]. Also, auto-control and intelligent regulation of connected vehicles effectively reduce time spent on commuting and energy consumption [62]. Studies on BD and IoT in the context of logistics show improvement opportunities like fatigue management for driver safety, predictive maintenance, on-time product delivery, transport route optimisation, truck sharing and transport planning [7], [11], [38], [69].

For last-mile deliveries, a combination of trucks and drones has been explored in recent research efforts. Drones are found to be highly cost-effective and environmentally sustainable if optimized route planning strategies. In this regard, there are recent applications of Operations Research Models for drones' routes optimisation (to and from trucks) with the objective of time and cost savings [70].

Concerning fleet management on maritime transport, financial fleet management can be improved by using artificial neural networks to predict the freight market of tankers, and AI and Big Data applications in navigational avoid vessel collisions by integration with the vessel traffic services. Other contributions are on early detection of vessel delay based on a data-driven method using a large amount of vessel tracking data from real-time satellite-automatic identification systems [55].

In general, vehicle usage optimisation research proposes the idea of using shared, fully loaded, energy-efficient PI vehicles with relays, which reduces transportation costs and carbon footprints. The vehicle usage optimisation theme is part of the PI literature, and contributions to this theme focus on the design and assessment of PI-enabled solutions for the optimisation of vehicle usage [10].

3) AUTOMATED GUIDED TASKS

Autonomous vehicles in conjunction with automatization and robotics enable performance, efficiency, efficacy, response time increases, and waiting times reduction throughout the SC [38], [71]. Autonomous vehicles extended with other technologies like IoT or CC can be used as cyber-physical systems (Automated guided vehicles) [7].

In addition, in the literature, there is special attention to applications on maritime logistic operations in the shipping industry, from basic operations to anchoring systems [55]. Bălan [40] present some contextual factors that lead to a disruptive impact on maritime transport. In the case of autonomous or unmanned ships/vessels, the author points out factors like the challenges for autonomous ship/vessel handlers in supporting situational awareness, as well as the harmony between ship/vessel, personnel and environment. Another challenge to consider is the skill loss by the ship/vessel handlers/crew members, which may follow the implementation of unmanned technology [71].

However, there are some cost changes in the case of autonomous ships/vessels compared to the conventional ships/vessels: more effective and efficient planning and dispatching strategies at platoon hubs will determine financial gains [70]; cost savings in terms of crew wages and crew related costs because of the absence of crew on board; cost increase related to personnel costs and operating costs of the shore control centre and to the cost of maintenance crews that improved design of the ships/vessels with direct influence on fuel consumption and greenhouse gas emissions; and the anticipated overall design of unmanned ships that will be significantly different in terms of hull design and propulsion arrangement [40].

4) WAREHOUSE LOCATION AND MANAGEMENT

Among the latest technological trends, those related to the use of analytical formulation and optimisation algorithms for the management of warehouses are viewed as crucial in logistics systems [41], [72]. Demand estimation and inventory optimisation can be carried out together in one single step by applying machine learning algorithms combining traditional operations research algorithms [56]. On the other hand, PI transit centres encourages the move from non-standardized proprietary transit centres to modern and open locations for efficient and effective cargo handling. Using coordination algorithms for matching demand and supply, the mission of PI transit centres is to efficiently and sustainably transfer PI-trailers from one truck to another [10].

In warehouse location/management, large infrastructure projects as the Belt and Road Initiative (BRI) or the Rail Baltica railway line have significant impacts [73], [74]. BRI project aims to revive the historic Silk Road trade route connecting Europe to East Asia via Central Asia. The BRI contributes to developing connectivity, supply chains, and international logistics along the Belt and Road because intermodal transportation and global logistics system go hand in hand [73]. Due to the magnitude of the project, BRI will have positive aspects on factors like labour cost, availability and stability of infrastructure, and market, supplier and knowledge access [75]. Also, additive manufacturing allows the concentration of the production of various low-volume, high customisation, high urgency parts [76]. So, this type of infrastructure projects and technologies will affect the characteristics and attractiveness of the different regions around the world, which is a determinant factor when making location decisions in a fully collaborative network. In these large infrastructure projects, decision support systems that embed operations research method can provide alternatives for the design and construction of the transport lines [74].

Concerning warehouse management, data transmitted from RFID integrated with cloud-based warehouse management systems can create remote positioning methods and indoor/outdoor GPS-based systems [44]. Also, CPS enable the automated warehousing systems that they are suited for application in many types of transport and material handling systems [65]. Also, CC has a positive effect on warehouse integration, as it integrates both the information flow and the physical flow by providing flexibility and agility, and facilitating resource sharing among participants throughout the SC life cycle [22].

The industrial deployment of IoT infrastructure enhances the order fulfilment platforms or collaborative warehouse platforms. Warehouse visibility, traceability, and transparency can be improved to facilitate competitiveness in a dynamic environment by utilising these ideal platforms for decentralised warehouse management [62]. Thus, implementing disruptive technologies on warehousing management boosts the SC performance thanks to an optimized physical asset, service sharing, and a reduction in warehousing cost [7], [38].

5) INVENTORY MANAGEMENT

The integration between IoT, BDA and Cloud-based systems allow stock reduction, errors decrease and inventory management improvement [7]. CC can contribute to supplier integration, apart from resource sharing, it enables the exchange of skills, know-how and production data. CC affords the company and suppliers real-time access to production and logistics data, and greater SC visibility and flexibility [22]. Improving forecast models, including anti-collision algorithms for RFID detection and automatic object localization reduce cost [7], [39]. Also, a better forecast of product demand not only diminish the uncertainty (thus the safety stock) but also allows planning preventive maintenance and reduced downtime of physical resources [77].

B. REAL-TIME INFORMATION PROCESSING

Under the PI perspectives, the seamless, secure and confidential data exchange research defines a set of open, shared and secure protocols for data exchange in PI-enabled open logistics networks. The latter implies to develop multiple data models, including canonical data and enterprise application integrations, to define a common set of data and information for information exchange and interoperability between participants in open logistics network [10].

This forces companies and data-sharing applications to improve, the capability to handle a large amount of real-time data and the end-to-end SC visibility. This can be done by including disruptive technologies. The adoption of Internet-based inter-organisational systems and Internet-based electronic data interchange has enhanced communication, coordination, and collaboration across organisational boundaries [31]. In this way, developing Big Data Analytics capability became mandatory for building competitive and sustainable SC [78]. This implies important challenges on the value of the information and how all this data should be shared and processed.

Concerning information sharing, Big Data technologies and CC have modernised traditional mechanisms between SC members [31], [55], [67]. Three types of changes can be observed: horizontal integration across the value chain, end-to-end engineering and vertical integration of networked manufacturing systems within the organization [19], [79]. In this sense, information transparency and proper communication between SC echelons, and the development of a single set of common standards to support collaboration are relevant enablers to real-time information processing [23]. Also, cloud-based collaboration increases technological proximity by integrating multiple sources in a system, so customers can use applications and services in the cloud, reducing the risk of out-of-date and incorrect information [22]. Besides, CC technologies enable storing a large volume of data and real-time monitoring, with information accessible to all SC members anywhere at any time [54], [77].

In terms of the benefits of instantaneous data processing, real-time information transmission between buyers and sellers facilitates the integration of physical flows, which affords greater agility and flexibility to respond to fluctuations in demand, as well as reduction in planning time, enhanced customer satisfaction and optimisation of decisions for reverse logistics [7], [31], [37], [38], [44], [77], [80]. Also, customer satisfaction increases can be achieved by constant communication, information flowing from the service provider and price competitiveness [81]. In addition, BDA and Blockchain encourages ethical behaviours among SC tiers because of traceability, transparency and moderate uncertainty by guaranteeing better quality and accuracy of the activities, which may increase commitment to sustainable practices and also the reputation of industries [54], [78], [82], [83].

Some applications mentioned in the literature are: to support navigation and scheduling tasks and to improve order assignment to containers [7]; IoT devices paired on blockchain networks to fight food fraud, counterfeit medicine and luxury jewellery like blood diamonds [21], [84], [85]; Real-time monitoring used to protect the environment because optimizing maritime traffic reduces the risk of accidents and minimizes environmental pollution [59]; and Blockchain-enabled real-time information tracking has applications as smart contacts, or document sharing and version control [84].

Despite all the benefits, the amount of shared information can cause a bottleneck produced by aspects like the low bandwidth and high latency of 3G/4G [86]. Thus, [86] argue that the 5G is expected to resolve those issues and to connect the SC partners for sharing those data in real-time. According to [87], 5G-enabled IoT increases the bandwidth capacity for the secure transmission of goods-related data.

1) RISK MANAGEMENT

In the risk management field, there are two types of contributions. The first assessing how disruptive technologies help to improve the current risk management activities, while the second type focuses on the emerging risks of implementing disruptive technologies in the operations.

BDA gives to organizations the ability to distinguish between risks that must be avoided and risks that must be taken. This is possible by identifying trends and events through monitoring publicly available news or social media channels associated with suppliers or specific sourcing markets [33]. Thus, organizations can continuously obtain updated information on suppliers and sourcing markets and quickly respond to changes or supply risks, even with contingency plans. Using blockchain technology for tracking cargo allows faster processing of insurance claims in cases where cargo has been lost or damaged, because tracking data on blockchains are trustworthy and traceable to the origin of loss [21], [88]. Thus, insurance companies can process the causes of the incident, the carrier involved, the type of cargo and the validity of the claims faster and easier. Also, ML can be used to model disruptive events and their impact on the supply chain to identify potential risks in a timely manner [89].

In maritime fleet risk management, the assessment of ship risks can be improved by: detection of anomalies in marine operations from data gathered on vessel movement; investigation of cargo loss in logistics systems employing data-driven analytics; and identification of how CC may become an enabler of dynamic and synchro modal container consolidation [40], [55].

As mentioned before, real-time data exchange and BDA methods combined with AI provides responsiveness, agility and flexibility to SC. However, it is important to guarantee transparency [66], [67], [90]. According to [81], data sharing in an intermodal network is complex, as the information systems used might be incompatible or there could be issues with speed, management capacity, the volume of information shared and the fear of revealing explicit information about the firms involved. For this reason, the influence of technological solution service providers could play a strategic role by promoting greater information and communication technologies adoption by network actors. Thus, transparency induces proactive behaviour in the SC members by enabling them to identify and respond to various changes and potential disruptions [66]. In this sense, the use of IoT technologies contributes to increasing reliability thanks to the elimination of information processing errors [38]. Also, from a systemic perspective, blockchain may leverage its potential through a large-scale collaboration of stakeholders as SC friction mainly stems from dispersed disconnection among parties [91]. Blockchain can be used to solve the issues related to double marginalization and information symmetry in the SC, by providing formal guarantees to the parties [92], [93].

Using IoT technology for real-time communications usually exposes smart devices to a range of security risks. So, the cybersecurity of each SC member is an issue that can decrease the level of trust [21]. Also, an issue with having a centralised cloud system for all IoT devices within an SC is its susceptibility to cyber-attacks that can make SC services unavailable until the cyber issue is eliminated [53]. From a data safety and integrity point of view, and due to the high cost of maintaining centralised IoT systems in SC and the security concerns surrounding IoT devices, one alternative is the application of blockchain networks [20], [42], [91].

Blockchain, as a distributed shared ledger technology, may help increase traceability and extend SC visibility by its consensus mechanism [91]. In this case, the transactions between IoT devices are protected by cryptography and are verified to ensure the originator of the message is not a malware or external intermediary [21], [42], [87]. Thus, decentralisation is a unique data security mechanism of the Blockchain [21], [53], [85], [92]. Regarding traceability, Blockchain sees large-scale deployment because a block could be created for each transaction following the product's digital footprint, from manufacturing to distribution and sale. Thus, every transaction along a Blockchain Supply Chain is fully auditable [85], [94], [95]. Even if Blockchain in the long term would yield to cost reduction, there are immediate implementation costs in the early adoption as those associate to incompatible blockchain models or upfront high costs for ''mining'' [92]. So, returns can occur at different times depending on the particular objectives of each application.

2) COOPERATIVE INVENTORY MANAGEMENT

Integration and interoperability allow SC members to work closely [66]. In vertical integration, functions inside companies work more effectively with technologies such as Enterprise Resource Planning being key to such integration. While horizontal integration can be achieved across the SC with Cloud Technologies, IoT and Digitalisation.

To achieve a high level of cooperative inventory management, the vendor managed inventory system uses, in conjunction with IoT, rapid and coordinated real-time inventory management across the SC and so permits a minimum yet nonetheless flexible inventory level that can address customer demand fluctuations [38]. According to [33], the use of BDA in vendor managed inventory systems collection, processing, and reporting on inventory data can inform decisions related to inventory performance improvement. Also, BDA helps to obtain a holistic view of inventory levels across the SC, while considering the impact of inventories at any given level or echelon. In consequence, it can help in decisions related to safety stock optimisation. The utilisation of the IoT in vendor managed inventory activities supports transparency, agility and efficiency by real-time and bidirectional information flows [7].

3) TRANSPORTATION COOPERATION

A freight transportation network includes multiple players (and multiple modes of transport) that do not necessarily trust each other and, in most cases, do not have a standardised method of sharing the transport data. In this case, using a customised blockchain that connects these parties would ensure sharing the required transaction and shipment data, which are both secure and reliable given the inherent features of the Blockchain [21]. Likewise, CPS, through enabling a high level of integration and information exchange, can enable a better understanding of the requirements of different parties and can enhance collaboration and cooperation between them [44].

According to the PI paradigm, it is expected that transport is organised and optimised in a decentralised way. In other words, for a given request, its best route from the origin to the destination will be updated every time it arrives at a PI-hub according to real-time, local information. To manage such decentralised systems, transport protocols and collaborative protocols will play a relevant role in guaranty the level of service and global optimality of the network [69].

In this vein, large infrastructure projects as the BRI must be taken into consideration. This connectivity comprises infrastructural, trade, and financial aspects [75]. From an infrastructural perspective, the BRI could be expected to contribute to establishing more resilient SCs, such as by increasing the quality and dependability of the logistics infrastructure [96]. BRI may enable other strategies for enhancing resilience, such as increasing visibility and enabling greater SC collaboration through greater connectivity. The latter is possible with the right implementation of the disruptive technologies presented in the framework [75].

A couple of studies on applications of transport cooperation are found by [69]. One, which investigates how information communication technology can help carriers dynamically show best transport plans by sharing real-time information. And the other, which investigates how shared information employed between collaborating shippers can help reduce CO2 emissions from freight transport in the grocery retail industry in the UK. Also, there are models where product distribution and delivery are underpinned by CC. These models show that it is possible to offer increasingly better delivery results as the number of participants in a collaboration environment grows [38].Finally, under the PI perspective, the cooperation models research attempts to redefine the existing practices for revenue sharing among different stakeholders in the new PI-enabled business models, such as PI hub holders and PI movers [10].

4) SMART CONTRACTS

In PI, the legal framework research aims to synchronize the incompatible legal environments associated with different countries to provide legal security and seamless international transport [10]. In this vein, the smart contracts become an important tool.

Smart contracts are programmable protocols that allow the execution of contract terms and agreements [85], [91]. This operation does not rely on an intermediary. Therefore, it not only speeds up the transaction but also promotes costs reduction and improves trust, since, within the network, all participants (nodes or actors) have a copy of the ledger [97]. The goal is to achieve effective and efficient flows of products and services, information, money, and decisions, to provide maximum value to the stakeholders [20], [85].

Smart contracts in transport and logistics, coupled with tracking tools, can facilitate payments to suppliers or 3PLs once they fulfil their tasks such as delivering goods to a warehouse or a port in a predefined specification [21]. Thus, the tracking device at a buyer's warehouse is connected to the Blockchain and once it receives the cargo from the supplier, it checks the quantity and the quality. This verification can be handled by using smart contracts running on 5G to track a shipment [87]. If all the stipulated conditions are met, the smart contract can automatically release the payment to the supplier [21]. Also, smart contracts can be used across cold chains to ensure that desirable conditions are maintained during manufacturing and transportation as well as issuing warning signs in case the sensors report any abnormalities across the chain [21], [87].

By utilizing a smart contract feature to execute digital signatures, the validation processes are speeded, because BCT provides trusted data from a single source. Enterprises may benefit from the reduced processing of paper-based documents as well as saving the considerable costs involved in tracking and obtaining proof of information authenticity [20], [72], [84], [91], [98]. Besides, smart contracts have the potential to solve or alleviate the problem of information asymmetry [93].

C. NEW BUSINESS MODELS

According to Treiblmaier *et al.* [10], up to 2019, business models were the most mentioned theme, on the physical internet literature. With the increase in the number of publications and the joint review of reviews of technologies and Physical Internet, we found more focused contributions. So, in the following we present the insights around new business models clustered in four main topics.

1) ADVANCED AUTOMATION

IoT allows the developing of self-monitoring capabilities where machines and devices can monitor and communicate their real-time performance [44]. This feature combined with intelligent devices, systems and production processes enable advanced automation throughout the entire SC that can lead to improved productivity efficiency and quality control [38]. This automation of processes results in less workforce requirement and process efficiency improvement [77].

Also, some articles show opportunities for using CPS and IoT regarding decentralisation and efficiency. Nonetheless, it is discussed that while higher degrees of autonomous control support goal achievement in logistics, although too much decentralisation could lead to obstructive chaotic systems [7].

2) CLOUD MANUFACTURING

Because of the increasing use of sensors on physical products, there is a vast potential for the development of sensor-based applications. For these reason, cloud manufacturing and IoT are interlinked. These applications may be used for preventive maintenance, to avoid stock-outs through monitoring inventory levels, for better capacity planning, and to assess the usage and functionality of products [67].

Other cloud manufacturing approaches, in productions logistics, are reported as part of [7] review. They show a case study where thanks to the synchronisation of an IoT-enabled production environment and a cloud supported resource management, it is possible to find improvements in delivery rates and inventory levels.

3) SERVICE MODELS

Even if most of the applications of CC that we found are related to data ingestion. Capabilities as storage, processing power, databases, networks, and software applications are key enablers of BDA capabilities. According to [22], [31], three different types of service models can be distinguished in CC. Infrastructure as a Service involves sharing data or IT infrastructure that can be used as a service. Platform as a Service entails providing a complete platform for application development and deployment on demand. Software as a Service where cloud providers host and manage the software application and underlying infrastructure, and handle any maintenance, like software upgrades and security patching. These services can be further deployed in four different ways: private cloud, community cloud, public cloud, and hybrid cloud. Recent studies state that cloud-computing services such as IaaS can be deployed on a community level to facilitate data sharing between SC partners within the network. Also, these studies argue that several business models based on CC such as Analytics as a service, Big Data as a service and Knowledge and information as a service will enhance BDA [31].

4) PI-ENABLING FIRMS

Several publications outline the PI as a key driver of business model innovation [11]. Thus, the actors in the logistic landscape can be divided into PI-enabling firms and PI-enabled firms. For example, virtualisation of supply chains enables to decouple physical flow from coordination and planning. It thus becomes a challenge to optimise flow in virtual supply networks that dynamically change their configuration depending on the state of the physical supply chain system [63]. In the same vein, the concept of digital twin shop-floor, based on the convergence of the physical and virtual worlds of the shop-floor, requires adapting the optimisation and forecasting actions [60].

New business models might be focused on auctioning, transit centre management, or less-than-truckload dynamic pricing in the PI. In general, the authors outline the need for transparency in PI business models to avoid principal-agent conflicts [11].

V. DISCUSSION

Based on the findings presented in the previous section, the research questions posed at the beginning of this review are answered. Below, we present the research results, as well as the implications for academics and practitioners offered from our tertiary study.

A. ADDRESSING THE RESEARCH QUESTIONS - RESEARCH RESULTS

RQ1. What are the main disruptive technologies and global initiatives impacting international multimodal freight movement and global transport networks?

The main disruptive technologies and global initiatives identified in our review were Blockchain, Cloud Computing, Cyber Physical Systems, Internet of Things, Big Data, Artificial Intelligence and Autonomous vehicles. However, other technologies and initiatives as The belt and road initiative, the augmented reality and the additive manufacturing were identified in a smaller proportion compared to those selected in the conceptual framework. The comprehensive list of documents selected and a resume of the taxonomy used is presented in Appendix.

As mentioned before, among these technologies, there are elements of the analytics field (Big Data and Artificial Intelligence). This is the reason why studying analytics and its relationship to SCM yields the attention of researches [35]–[37].

RQ2. What are the key activities, knowledge areas and strategies in SCM where the PI and disruptive technologies are game-changing?

In the conceptual framework presented in Figure 4, we consolidate and summarise the findings in three clusters with subclusters.

First, the decision-making tools which impacts the management of the smart goods, vehicles and infrastructure, the fleet, the automated guided task, the warehouse and the inventory.

The second cluster, where the real-time information processing and sharing impacts the risk management, the cooperative inventory management, the transportation cooperation and the smart contracts.

Finally, the third cluster on the new business models that are going to create or modify the roles of the SC players. There we identify subclusters of new business models in advanced automation, cloud manufacturing, as a service models and PI enabling firms.

RQ3. What are the main applications of the disruptive technologies in favour of the SCM?

The description of the conceptual framework, presented in Sections IV-A - IV-C, presents in detail the application of the selected technologies in each of the KAS subclusters identified. Results in Section IV-A show that the integration of disruptive technologies led to enhance the global performance of an SC. Each technology provides a special characteristic not also to SCM but also to PI themes. Thus, IoT offers the possibility of generating a huge amount of data [44]. BDA brings the tools to analyse and extract valuable information from the collected data [31]. CC relates to the infrastructure where the data can be managed and gives the desirable interconnectivity [22]. Cyber-physical systems enhance productivity by enabling an elevated level of integration and information sharing [65]. Blockchain is seen as a key technology to mitigate security and transparency issues [90]. However, several applications need some minimum connectivity requirements that are expected to be solved by the implementation of 5G connectivity worldwide [86].

Further, a fully connected network would enable not only to minimise costs and time, and maximise users' profits, but also to increase safety and to fight illegal activities (see Section IV-B) [21], [84], [85]. Nevertheless, access to information, top-notch technology and infrastructure investment capabilities are essential to boost the implementation of the PI initiative worldwide. The changing structure of supply networks strengthens the need for collaborations and therefore, the urgency for efficient communication and data exchange [10], [44], so there is expected to be a significant development of new business models that will enable these transformations (see Section IV-C) [10].

RQ4. How are the main applications of emerging disruptive technologies and existing tech solutions in SCM related to PI elements?

In figure 4, we draw the relations with the PI themes in such a way that the reader can identify how the elements are impacted from by KAS in an operational decision level, in a tactical decision level, and in a strategical decision level. In the operation decision level, the modular containers can take profit the of the integration of disruptive technologies in the decision-making tools, and of the management of smart goods, vehicles and infrastructure. Vehicle usage utilization is highly related with the fleet management and the automated guided task, which includes the management of autonomous vehicles. Likewise, the transit centres are related to the automated guided task, but also to the warehouse location and management and the inventory management.

In the tactical decision level, data exchange is enabled by the technological development around the real-time information processing and can be supported by the risk management field. The cooperation models in PI are impacted by the risk management, the cooperative inventory management, the transportation cooperation and the implementation of smart contracts. In this case, disruptive technologies helps to overcome scalability, security and reliability issues.

And in the strategical decision level, the legal framework theme is related to the smart contracts implementation, which allows the players to reduce the number of intermediaries and therefore to speed up the cooperation and the transactions between players. Finally, the development of new business models around the PI are aligned to the development of advanced automation, cloud manufacturing, service models and PI dedicated firms.

B. IMPLICATIONS FOR ACADEMICS

For researchers, this study sheds light on the PI and provides new insights into the relationship between disruptive technologies, PI components and SCM. The conceptualisation of these relations helps academic researchers to embark on new empirical research in this domain. The proposed framework offers intuitions into possibilities to enhance existing logistics systems and improve technological solutions. Moreover, this framework exposes the importance of multidisciplinary research groups working on the design of the future of freight transport.

C. IMPLICATIONS FOR PRACTITIONERS

For practitioners, this paper shows advantages, initiatives and risks related to implementing certain technologies on the transportation tasks and how these contribute to the PI, as well as how these allow for improvements in the performance of SCs, which is an essential field in the engineering management. Also, as countries/companies invest in the development of the PI, it is relevant for managers to have exposure to such concepts and to be updated on the development of disruptive technologies for the future of transportation worldwide. Likewise, the proposed framework is useful to assess the potential effects on companies and to support strategic decision-making.

VI. CONCLUSION AND FUTURE RESEARCH

This paper studies literature reviews around disruptive technologies, PI, and SCM fields. A Systematic Literature Review identifying more than twelve thousand articles and covering 74 review papers is conducted to identify, select, analyse and synthesise the relevant literature on the integration of disruptive technologies, PI and SCM.

The major findings of this paper refer to the identification of the key activities, knowledge areas and strategies in the SC field where the PI and disruptive technologies are game-changing. These findings are condensed on a conceptual framework that summarises the relationships that exist between relevant disruptive technologies, the PI topics and SC key activities.

While a systematic and structured literature review is conducted, it is worth recognising the concerns associated with this paper. The main limitations of this study are attributed to the selection criteria of the documents. First, the use of specific keywords to cover a topic holding a wide variety of knowledge fields. We implemented a forward and backward searchers based on the citations to have a snowballing effect to mitigate this bias risk. Second, this is a tertiary study covering systematic literature reviews. Third, we do not to include conference papers, which might be discussing tendencies, to focus on journal papers and book chapters. The results are limited to the discussion presented in those reviews. Despite these limitations, as the SLR technique is rigorously applied, it is possible to obtain significant knowledge about the research questions [12].

The findings also helped to identify gaps in the literature to be filled by developing new lines of research in the future.

From an operational level and considering that organisations are likely to continue developing their analytics capabilities, research might explore the best interactions between data, Operations Research Methods and AI algorithms to optimise and deploy decision-making tools in the SC network. These methods must integrate different forms of data while facing issues of complexity dimensionality, scalability, and interoperability of the problems to be solved. In addition, it is relevant to discuss the adoption of technologies in business cases, and thus consolidate raw data to show the economic benefits on different industrial scenarios. Thus, we expect to see more research on predictive and prescriptive analytics.

From a tactical perspective, a research stream might look to define the required abilities, skills, and knowledge of the personnel to keep the new systems running efficiently. Thus, it is important to design strategies to connect professionals with diverse backgrounds by a standardised language around the systems. Other stream might focus on defining protocols and standards to check, measure and control data through inter-organisational SC networks.

From a strategical perspective, we foresee some relevant streams. First, analyse the organisational context under which companies achieve success or failure implementing disruptive technologies and moving towards the PI in an early stage. So, case studies are needed to prove key factors to implementation, to set priorities, and to examine cost trade-offs by analysing various stages of implementation. Second, for companies and governments, it is important to figure out if disruptive technologies are a substitute for the current information systems and decision-making tools or are complimentary of the current ones. Third, it is relevant to show what role the governments play in adopting disruptive technologies, international standards, and protocols. Also, due to real time-sharing data involves all type of partners around the world, it is important to diagnose how the boost obtained by the development of the PI initiative and technological adoption is going to change less developed regions. Lastly, a research stream might be designing and proving new business models into a fully collaborative supply environment and circular economy.

APPENDIX

The following table presents an abstract of the taxonomy developed in the SRL. In the table the paper reference (Ref), the research question (RQs), the number of documents reviewed (ND), the time horizon covered (TH), and the technologies mentioned in each literature review (Tech) are presented.

Ref	RQs	ND	TH	Tech
[65]	1. What are the current technological advancements in the circular supply chain? 2. What are the major challenges and barriers in implementing a circular supply chain to build circular business models? 3. What are the technological inclusions in the CSC currently needed for the effective design and implementation of CBMs?	96	2010-2021	I4.0; BCT; BDA; AI; CPS; IoT; CC; AR; OR
[81]	1. Changes that have occurred in freight transport modes comprising two or more successive transport modes. 2. Principles governing the way that intermodal freight transportation works. 3. Aspects that have to be taken into account to optimise the intermodal transportation system. 4. The relationship that exists between the freight transport mode and logistics performance.	127	1990-2016	ICT
[49]	1. What are the different types of research methodologies and data analysis adopted to assess the application of ML in LSCM? 2. How have the following themes such as publishers, geographic locations, author affiliations and industry engagement changed over the years? 3. What ML concentration, techniques and algorithms are frequently used in LSCM? 4. What are the main roles of ML in LSCM, and how could they contribute to the success of LSCM and future research directions?	110	1994-2019	I4.0; BDA; AI; IoT; OR
[17]	1. Are the current synchromodal and PI research streams well intertwined in order to meet the visions and goals set by ALICE and the European Commission?	53	2010-2017	PI; BDA; IoT; CC; ICT; OR
[31]	Not defined	82	2008-2016	BDA; IoT; CC; OR
[23]	1. What are the Industry 4.0 enablers of sustainable supply chain management? 2. Can a model be developed by integrating the concept of Industry 4.0 and sustainable supply chain management?	53	1998-2017	I4.0; BDA; CPS; IoT; CC; OR
[40]	1. In what context and by means of what mechanism does the implementation of future advanced ICTs have disruptive impact on maritime transport?	24	2010-2018	AGV; BDA; CPS; IoT; CC; ICT; OR

Ref	RQs	ND	TH	Tech
[34]	1. Which research methods and theories have been used to characterise and study the use BDA in SCM? 2. How has BDA been used to manage SCM resources? 3. In which SCM processes has BDA been used?	44	2005-2016	BDA; AI; IoT; CC; ICT; OR
[98]	1. How is the industry structured for the transportation sector? 2. What are the trends in published knowledge on blockchain for the transportation sector? 3. How does blockchain impact the activities in the transportation sector?	26	2017-2020	AGV; BCT; AI; IoT
[20]	1. What are the drivers for using BCT in SCM? 2. What are the BCT applications in SCM? 3. What are the limitations and success factors of applying BCT in SCM? 4. What is the impact of each BCT application on SC objectives? 5. To what extent is BCT applicable in the SCM field?	31	2016-2019	BCT; IoT
[94]	1. How is trust operationalised and discussed in the articles that addressed both supply chain management and blockchain technology? 2. How can blockchain technology influence trust in supply chain management?	55	2016-2020	BCT; IoT
[63]	Not defined	166	2008-2017	I4.0; BDA; AI; CPS; IoT; CC; OR
[68]	1. What is the impact of challenges and subsequent risks of IoT for SCM? 1.1 How can the literature on challenges and risks of IoT in SCM be classified? 1.2 How do the challenges and risks affect future SCs?	102	2008-2017	I4.0; BCT; BDA; IoT
[61]	1. The objective of this paper is to investigate existing academic research into the opportunities and potentials of Industry 4.0 in the context of the TBL and SCM	55	2014-2019	I4.0; BCT; BDA; AI; IoT; CC; AR
[53]	Not defined	109	2013-2019	I4.0; BCT; BDA; AI; IoT; CC

Ref	RQs	ND	TH	Tech
[91]	1. What are the main topics and subjects of interest in supply chain studies that utilize blockchain technology; how do they address its core issues; and how have these topics evolved over time? 2. What are the main research methodologies employed in blockchain-based supply chain literature and how are they related to the main topics? 3. Which blockchain-supply-chain papers were most instrumental in driving the development of literature thus far?	106	2016-2019	I4.0; BCT; IoT; CC
[45]	1. How is the concept of Industry 4.0 defined and operationalized in the literature? 2. What are the main topics, trends and theories in the debate on Industry 4.0 in SCM? 3. What are the potential avenues for future research and practice in this area?	334	2011-2018	I4.0; BDA; CPS; IoT; CC; 3D-AM; AR; OR
[54]	Not defined	116	2013-2019	I4.0; BDA; IoT; OR
[70]	1. What are the major emerging technologies in freight transportation? 2. How do those technologies impact freight transportation?	415	2008-2019	AGV; I4.0; BCT; BDA; AI; IoT; CC; 3D-AM; AR; OR
[95]	1. What are the latest blockchain applications focused on disruption risk management? 2. How are blockchain solutions used to identify potential disruption risks?	192	2017-2020	AGV; I4.0; BCT; BDA; AI; IoT; CC; 3D-AM
[44]	1. What are the key enablers of Industry 4.0 and their potential capabilities? 2. How can Industry 4.0 influence individual supply chain processes and supply chain as a whole?	160	2005-2019	I4.0; BDA; AI; CPS; IoT; CC; 3D-AM
	3. What impact improved supply chain processes can have on supply chain performance?			
[99]	1. What is the current state of research regarding the impact of I4.0 on sustainable production and operations management? 2. What is the impact of I4.0 on the economic, environmental, and social dimensions of sustainability?	89	2010-2020	AGV; I4.0; BCT; BDA; AI; CPS;

Ref	RQs	ND	TH	Tech
				IoT; CC; AR; ICT
[66]	1. What are the constructs that shape the Supply Chain 4.0 concept? 2. How can the evolution of Supply Chain 4.0 be understood and evaluated? 3. What are the open research questions and research gaps related to Supply Chain 4.0 and its maturity?	36	2011-2018	I4.0; BDA; AI; CPS; IoT; CC; 3D-AM; AR
[59]	1. What is the current status quo of digitization in maritime logistics? 2. What are the future challenges of digitization in maritime logistics?	124	2003-2017	AGV; I4.0; BDA; AI; CPS; IoT; CC; AR; ICT; OR
[50]	1. Is any prognostic capability provided with reference to future scenarios that may affect the Decision Support Systems (DSS)? 2. Is there any exploitation of large data sets in the decision making process? 3. How many factors are considered when developing the DSS? 4. Is any learning capability developed to address decision making in OR?	69	2008-2017	BCT; BDA; AI; IoT; OR
[78]	1. What do we know about the use of big data in digitally-enabled sustainable supply chains?	33	2015-2019	I4.0; BCT; BDA; AI; CPS; IoT; CC; OR
[39]	Not defined	70	2015-2020	I4.0; BCT; BDA; AI; CPS; IoT; CC; OR
[67]	1. What are different research approaches used to study Industry 4.0? 2. What is the current status of research in the domains of Industry 4.0?.	85	2012-2017	I4.0; BCT; BDA; CPS; IoT; CC; 3D-AM; AR; OR
[51]	1. How has Visual Analytics(VA) been used to support the SC activities? 1.1. What are the use cases of VA related to the SC activities? 1.2. Which decision areas of the SC activities are supported by VA? 1.3. How have the SC data been used for visualization? 2. Which VA techniques or tactics have been used in SC? 2.1. What type of data visualizations have been used? 2.2. What type of data analytics have been used in the SC VA?	23	Not Clear	BDA; AI; AR; ICT
[83]	1. What are the applications of blockchain technology in sustainable manufacturing? 2. How can blockchain attributes enhance the sustainable performance of manufacturers?	21	2018-2021	I4.0; BCT; BDA; AI; IoT; CC
[46]	1. Which combinations of IoT devices and analytical models are commonly applied during SCM and logistics operations? 2. How do the IoT's analytical capabilities affect supply chain decision making? 3. What type of supply chain improvements result from IoT-driven decision making?	79	1997-2019	I4.0; BDA; AI; CPS; IoT; CC; ICT; OR
[82]	Not defined	22	2018-2020	BCT
[76]	1. What are the key themes in the literature on the application of AM in the different areas of the supply chain? 2. Which benefits and challenges are identified in the literature concerning the application of AM in the different areas of the supply chain? 3. Which research avenues can be identified for the application of AM in the different areas of the supply chain?	141	2011-2019	BCT; 3D-AM
[41]	Not defined	152	2010-2018	AGV; I4.0; BCT; BDA; IoT; CC; 3D-AM; ICT; OR
[57]	Not defined	Not clear	2000-2015	BDA
[62]	Not defined	91	2005-2017	IoT
[80]	1. How has BDT-enabled SCM studies been operationalised? 2. What is the nature of the evidence that support the value-added potential of BDT in SCM? 3. How has the value of BDT been captured in extant SCM studies?	83	2014-2019	BDA; IoT; OR
[87]	Not defined	Not clear	2015-2019	AGV; I4.0;

Ref	RQs	ND	TH	Tech
				BCT; BDA; CPS; IoT; CC; 3D-AM
[100]	1. What is the existing knowledge available on Industry 4.0 and SCS? 2. What are the technologies of Industry 4.0 that drive sustainability in the supply chain network?	55	2016-2020	AGV; I4.0; BCT; BDA; AI; CPS; IoT
[56]	1. What is the knowledge structure of research on data driven OSCM from 2000 to early 2020 (published from2000 to 2019 or accepted for publication before 2020)? 2. Are there any topics on data-driven OSCM which have recently been heeded by both scholars and practitioners or integrated into an established subfield?	120	2000-2019	I4.0; BDA; AI; IoT; OR
[19]	Not defined	52	2012-2017	I4.0; BCT; BDA; AI; CPS; IoT; CC; 3D-AM; AR; ICT; OR
[22]	1. What are the findings to date, the areas of study developed and the research gaps related to Cloud Computing (CC) use in the firm and its effect on Supply Chain Integration (SCI)? 1.1. What is the current state of knowledge of Cloud Computing (CC) use in the firm and its effect on Supply Chain Integration (SCI)? 1.2. What are the main research directions in relation to the adoption of CC for SCI? 1.3. What are the gaps and future research directions that can be identified based upon existing work?	77	2010-2017	BCT; BDA; CPS; IoT; CC; AR
[38]	1. Analysis of the state of knowledge that exists in the literature on the relationships between IDT of I4.0 and LSCM. 1.1. What categories of papers have been published to date? 1.2. Is it possible to identify a taxonomy of the current research on IDT of I4.0 and Lean Supply Chain Management and the relationship between the IDT of I4.0 and LSCM?	78	1996-2019	AGV; I4.0; BCT; BDA; AI; CPS; IoT; CC; AR; OR

Ref	RQs	ND	TH	Tech
	1.3. What gaps exist in the literature on IDT of I4.0 and LSCM and what direction should future research go in?			
[88]	1. What are the key findings of this literature review? 2. Who: Identify researchers in the area of our research interest and the most active researchers. 3. Where: Identify the journals that have published research in the area of our research interest. 4. When: Identify the span of time for which research has been conducted in the area of our research interest. 5. How: How is research in this area going to change the way business is conducted? Identify the new business models in this area. 6. Why: Why is it important for researchers to conduct research in this area? Why is it necessary to further examine this research area if it has already been studied in great detail?	187	2015-2020	PI; I4.0; BCT; BDA; AI; CPS; IoT; CC
[69]	1. From an industrial perspective, what are the existing practicable HCT solutions? And how should logistics companies (e.g. carriers, LSP, shippers, receivers) adopt effective and efficient HCT solutions, by taking into account their position, resources, and responsibility in the SC, while being aware of the underlying issues and challenges when implementing the solutions (called implementation issues in this paper)?	120	2007-2017	PI; IoT; OR
	2. From an academic perspective, what are the current trends of solution innovation? And how can these innovative solutions stimulate current research problems or bring up new problems to the field?			
[90]	Not defined	23	2017-2021	BCT
[21]	1. What is the latest progress made by the scientific literature to examine the adoption and implementation of blockchain technology in supply chains, logistics and transport operations? 2. What are some of the key knowledge areas in the supply chain, logistics and transport studies that blockchains can contribute to? 3. What are some of the key research questions to be addressed in each knowledge area? 4. Which future applications and research streams can be envisaged for blockchains in supply chains and logistics aside from the current use cases?	48	2016-2018	BRI; BCT; BDA; AI; IoT
	1. What are the main current			

Ref	RQs	ND	TH	Tech
[21]	by the scientific literature to examine the adoption and implementation of blockchain technology in supply chains, logistics and transport operations? 2. What are some of the key knowledge areas in the supply chain, logistics and transport studies that blockchains can contribute to? 3. What are some of the key research questions to be addressed in each knowledge area? 4. Which future applications and research streams can be envisaged for blockchains in supply chains and logistics aside from the current use cases?	48	2016-2018	BRI; BCT; BDA; AI; IoT
[42]	1. What are the main current blockchain applications in SCM? 2. What are the main disruptions and challenges in SCM because of blockchain adoption? 3. What is the future of blockchains in SCM?	27	2008-2018	I4.0; BCT; CPS; IoT; 3D-AM; OR
[77]	RQ1: Identification of the key enabling technologies towards I4.0 in the manufacturing & SCM context? RQ2: The present status of current literature on enabling technology implementation and adoption in practice? RQ3: What are the under-explored research areas and upcoming research avenues for I4.0-ET?	86	2005-2019	I4.0; BCT; BDA; AI; CPS; IoT; CC; 3D-AM; AR
[60]	1. How can applications in the operations field using IoT affect supply-chain performance?	171	2000-2020	AGV; I4.0; BCT; BDA; CPS; IoT; CC; 3D-AM; OR
[71]	1. What are the potentials and challenges of deploying drones in SCM and logistics? 2. What are the current research gaps in the extant literature?	55	2009-2020	PI; AGV; I4.0; BCT; BDA; AI; IoT; CC; AR; OR
[43]	1. What are the general research trends of AI applications in supply chains? 2. What are the supply chain outcomes that AI achieves? 3. What level of AI drives such outcomes?	136	1996-2020	AGV; BDA; AI; IoT; CC; OR
[43]	1. What are the general research trends of AI applications in supply chains?	136	1996-	AGV; BDA;
	2. What are the supply chain outcomes that AI achieves? 3. What level of AI drives such outcomes?		2020	AI; IoT; CC; OR
[55]	1. Toward Digitalization of Maritime Transport?	99	Not Clear	AGV; I4.0; BCT; BDA; AI; IoT; CC; 3D-AM; AR; OR
[89]	1. In which supply chain areas has ML already been considered for implementation in SC Risk Management (SCRM) both in literature and practice? 2. Which are primary risks considered in the use-cases? 3. How might ML shape and improve SCRM?	23	1997-2020	BCT; BDA; AI; IoT; CC
[11]	Not defined	46	2011-2017	PI; IoT; OR
[86]	1. How the emerging 5G will be able to overcome the current bottleneck of information (i.e. data and content) exchange in supply chain. How is the literature developed around it?	9	2013-2019	AGV; I4.0; BCT; BDA; AI; CPS; IoT; CC; 3D-AM; AR; ICT
[58]	1. What are the statistical dimensions of research evidence related to the existing studies on Big Data in OSCM? 2. What are the emerging themes and findings focused upon by the selected studies in the area? 3. What are the research gaps in the existing investigations? 4. How can the research and practice in this area be taken forward?	116	2015-2020	BDA; AI; IoT; CC; ICT
[75]	1. How is China's BRI portrayed in the broad literature? 2. How will the BRI impact global supply chain management? 3. What does this mean for the supply chain management literature?	173	2013-2018	BRI; BDA
[80]	1. What is the existing state of understanding and knowledge available on Industry 4.0 and SCI? 2. What are the core research directions with reference to the adoption of Industry 4.0 and SCI? 3. What are future research directions need to be recognized based upon existing works and identified potential research gaps?	59	2011-2020	I4.0; BCT; BDA; AI; CPS; IoT; CC; 3D-AM; AR; ICT

Ref	RQs	ND	TH	Tech
[47]	1. How does AI contribute to SCM studies?	64	2008-2018	I4.0; BCT; BDA; AI; IoT; CC
[10]	Not defined	192	2006-2019	PI; I4.0; BCT; BDA; IoT; CC; ICT; OR
[93]	1. How to structure a supply chain that incorporates the blockchain? 2. How to manage a supply chain that incorporates the blockchain?	Not clear	Not clear	BCT; IoT
[92]	1. What challenges have been addressed in the current research on Blockchain? 2. What opportunities have been addressed in the current research on Blockchain? 3. What applications have been addressed in the current research on Blockchain?	89	2008-2018	BCT; BDA; CPS; IoT
[72]	Not defined	60	2008-2020	I4.0; BCT; AI; IoT; CC; OR
[97]	Not defined	37	2008-2020	I4.0; BCT; AI; IoT
[64]	1. What BCT functionalities and organisational factors are related to BCT connectivity in SC? 2. How do BCT functionalities and organisational factors influence interaction or vice versa? 3. How does the BCT connectivity affect SC interaction and resilience? Or what BCT connectivity inhibitors can negatively affect SC interaction and resilience?	89	2015-2020	I4.0; BCT; IoT
[96]	Not defined	61	2005-2015	BRI; OR
[84]	1. How blockchain technology has an impact on information sharing in the supply chain.	31	2008-2019	BCT; IoT
[85]	1. How will the blockchain influence future supply chain practices and policies?	29	2008-2017	BCT; BDA; IoT
[33]	Not defined	101	Not Clear	BDA; OR
[7]	1. Which characteristics should be included in a covering concept of Logistics 4.0? 2. What is the state of knowledge in Logistics 4.0 research? 3. Which aspects of Logistics 4.0 are currently underrepresented but promising to fulfil the requirements of these systems?	114	2005-2018	AGV; I4.0; BCT; BDA; CPS; IoT; CC; 3D-AM; AR; OR
[52]	Not defined	103	2014-2019	PI; AGV; I4.0; BDA; AI; CPS; IoT; CC; AR; OR
[37]	1. How do big data and BDA contribute to Supply Chain Planning? 2. What are the factors determining BDA-adoption decisions in organisations and supply chains?	72	Not Clear	BDA; AI; CPS; IoT
[48]	1. To explore the application of AI and ML in SC and what has been published in this field.	50	2009-2021	AGV; I4.0; BCT; BDA; AI; IoT; OR

AGV: Autonomous Vehicles/Automated Guided Vehicles; **I4.0:** Industry 4.0; **BCT:** Blockchain; **AI:** Artificial Intelligence; **BDA:** Big Data/ Big Data Analytics; **CPS:** Cyber-Physical Systems; **CC:** Cloud Computing; **IoT:** Internet of Things;**BRI:** Belt and Road Initiative; **AR:** Augmented Reality; **3D-AM:** 3D printing/Additive Manufacturing; **ICT:** Information and Communication Technologies; **OR:** Operations Research tools (optimisation models, mathematical programming, simulation, metaheuristics)/ Prescriptive analytics.

REFERENCES

[1] W. Jing, Y. Yan, I. Kim, and M. Sarvi, "Electric vehicles: A review of network modelling and future research needs," *Adv. Mech. Eng.*, vol. 8, no. 1, Jan. 2016, Art. no. 168781401562798.

[2] J. Olivier and J. Peters, "Trends in global CO_2 and total greenhouse gas emissions: Report 2019," PBL Netherlands Environ. Assessment Agency, The Hague, The Netherlands, Tech. Rep. 2, vol. 5, 2019.

[3] International Energy Agency. (2018). *CO_2 Emissions From Fuel Combustion 2018 Highlights*. [Online]. Available: https://webstore.iea.org/co2-emissions-from-fuel-combustion-2018-highlights

[4] M. S. Islam, S. Moeinzadeh, M.-L. Tseng, and K. Tan, "A literature review on environmental concerns in logistics: Trends and future challenges," *Int. J. Logistics Res. Appl.*, vol. 24, no. 2, pp. 126–151, Mar. 2021.

[5] B. Farahani, F. Firouzi, and M. Luecking, "The convergence of IoT and distributed ledger technologies (DLT): Opportunities, challenges, and solutions," *J. Netw. Comput. Appl.*, vol. 177, Mar. 2021, Art. no. 102936.

[6] B. Montreuil, "Toward a physical internet: Meeting the global logistics sustainability grand challenge," *Logistics Res.*, vol. 3, nos. 2–3, pp. 71–87, May 2011.

[7] S. Winkelhaus and E. H. Grosse, "Logistics 4.0: A systematic review towards a new logistics system," *Int. J. Prod. Res.*, vol. 58, no. 1, pp. 18–43, Jan. 2020.

[8] K. Jharni, M. Hlyal, and J. E. Alami, "Physical internet: Literature review and research opportunities," *IOP Conf. Ser., Mater. Sci. Eng.*, vol. 827, no. 1, Apr. 2020, Art. no. 012044.

[9] C. Fergani, A. E. B. E. Idrissi, A. Hajjaj, and S. Marcotte, "Physical internet characterization," in *Proc. Int. Colloq. Logistics Supply Chain Manage. (LOGISTIQUA)*, Jun. 2019, pp. 1–7. [Online]. Available: https://ieeexplore.ieee.org/document/8907244/

[10] H. Treiblmaier, K. Mirkovski, P. B. Lowry, and Z. G. Zacharia, "The physical internet as a new supply chain paradigm: A systematic literature review and a comprehensive framework," *Int. J. Logistics Manage.*, vol. 31, no. 2, pp. 239–287, May 2020.
[11] H. Sternberg and A. Norrman, "The physical internet—Review, analysis and future research agenda," *Int. J. Phys. Distrib. Logistics Manage.*, vol. 47, no. 8, pp. 736–762, Sep. 2017.
[12] D. Denyer and D. Tranfield, "Producing a systematic review," in *The Sage Handbook of Organizational Research Methods*, D. Buchanan and A. Bryman, Eds. Thousand Oaks, CA, USA: SAGE Publications, 2009, pp. 671–689.
[13] *Future of Supply Chain Technology*, Gartner, Stamford, CT, USA, 2020, pp. 1–4. [Online]. Available: https://studylib.net/doc/25547602/supply-chain-technology-trends
[14] E. Ballot, "The physical internet," in *Operations, Logistics and Supply Chain Management*. Cham, Switzerland: Springer, 2019, pp. 719–734.
[15] H. Treiblmaier, "Combining blockchain technology and the physical internet to achieve triple bottom line sustainability: A comprehensive research agenda for modern logistics and supply chain management," *Logistics*, vol. 3, no. 1, p. 10, Feb. 2019.
[16] B. Montreuil, R. D. Meller, and E. Ballot, "Towards a physical internet: The impact on logistics facilities and material handling systems design and innovation," in *Proc. Prog. Mater. Handling Res.*, 2010, pp. 305–327.
[17] T. Ambra, A. Caris, and C. Macharis, "Towards freight transport system unification: Reviewing and combining the advancements in the physical internet and synchromodal transport research," *Int. J. Prod. Res.*, vol. 57, no. 6, pp. 1606–1623, Mar. 2019.
[18] *Alliance for Logistics Innovation Through Collaboration in Europe*, Eur. Technol. Platform ALICE, Europe, 2017. [Online]. Available: https://www.etp-logistics.eu/
[19] K. Nosalska, Z. M. Piątek, G. Mazurek, and R. Rządca, "Industry 4.0: Coherent definition framework with technological and organizational interdependencies," *J. Manuf. Technol. Manage.*, vol. 31, no. 5, pp. 837–862, Nov. 2019.
[20] A. Batwa and A. Norrman, "A framework for exploring blockchain technology in supply chain management," *Oper. Supply Chain Manage., Int. J.*, vol. 13, no. 3, pp. 294–306, Apr. 2020.
[21] M. Pournader, Y. Shi, S. Seuring, and S. C. L. Koh, "Blockchain applications in supply chains, transport and logistics: A systematic review of the literature," *Int. J. Prod. Res.*, vol. 58, no. 7, pp. 2063–2081, Apr. 2020.
[22] L. Novais, J. M. Maqueira, and Á. Ortiz-Bas, "A systematic literature review of cloud computing use in supply chain integration," *Comput. Ind. Eng.*, vol. 129, pp. 296–314, Mar. 2019.
[23] S. Bag, A. Telukdarie, J. H. C. Pretorius, and S. Gupta, "Industry 4.0 and supply chain sustainability: Framework and future research directions," *Benchmarking, Int. J.*, vol. 28, no. 5, pp. 1410–1450, Dec. 2018.
[24] A. Aryal, Y. Liao, P. Nattuthurai, and B. Li, "The emerging big data analytics and IoT in supply chain management: A systematic review," *Supply Chain Manage., Int. J.*, vol. 25, no. 2, pp. 141–156, Dec. 2018.
[25] Z. Inamdar, R. Raut, V. S. Narwane, B. Gardas, B. Narkhede, and M. Sagnak, "A systematic literature review with bibliometric analysis of big data analytics adoption from period 2014 to 2018," *J. Enterprise Inf. Manage.*, vol. 34, no. 1, pp. 101–139, Jan. 2021.
[26] P. Dhamija and S. Bag, "Role of artificial intelligence in operations environment: A review and bibliometric analysis," *TQM J.*, vol. 32, no. 4, pp. 869–896, Mar. 2020.
[27] Y. Gu, J. C. Goez, M. Guajardo, and S. W. Wallace, "Autonomous vessels: State of the art and potential opportunities in logistics," *Int. Trans. Oper. Res.*, vol. 28, no. 4, pp. 1706–1739, Mar. 2020, doi: 10.1111/itor.12785.
[28] Lloyd's Register. (2018). *Shipright Design and Construction: Design Code for Unmanned Marine Systems*. [Online]. Available: https://www.cdinfo.lr.org/information/documents/ShipRight/Design%20and%20Construction/Additional%20Design%20Procedures/Design%20Code%20for%20Unmanned%20Marine%20Systems/Design%20Code%20for%20Unmanned%20Marine%20Systems,%20February%202017.pdf
[29] D. Tranfield, D. Denyer, and P. Smart, "Towards a methodology for developing evidence-informed management knowledge by means of systematic review," *Brit. J. Manage.*, vol. 14, no. 3, pp. 207–222, Sep. 2003.
[30] M. Aria and C. Cuccurullo, "*bibliometrix*: An R-tool for comprehensive science mapping analysis," *J. Informetrics*, vol. 11, no. 4, pp. 959–975, Nov. 2017.
[31] D. Arunachalam, N. Kumar, and J. P. Kawalek, "Understanding big data analytics capabilities in supply chain management: Unravelling the issues, challenges and implications for practice," *Transp. Res. E, Logistics Transp. Rev.*, vol. 114, pp. 416–436, Jun. 2018.
[32] J. J. Cochran, *Informs Analytics Body of Knowledge*. Hoboken, NJ, USA: Wiley, 2018.
[33] G. Wang, A. Gunasekaran, E. W. T. Ngai, and T. Papadopoulos, "Big data analytics in logistics and supply chain management: Certain investigations for research and applications," *Int. J. Prod. Econ.*, vol. 176, pp. 98–110, Jun. 2016, doi: 10.1016/j.ijpe.2016.03.014.
[34] M. W. Barbosa, A. D. L. C. Vicente, M. B. Ladeira, and M. P. V. D. Oliveira, "Managing supply chain resources with big data analytics: A systematic review," *Int. J. Logistics Res. Appl.*, vol. 21, no. 3, pp. 177–200, May 2018, doi: 10.1080/13675567.2017.1369501.
[35] S. Maheshwari, P. Gautam, and C. K. Jaggi, "Role of big data analytics in supply chain management: Current trends and future perspectives," *Int. J. Prod. Res.*, vol. 59, no. 6, pp. 1875–1900, Mar. 2021.
[36] I. Lee and G. Mangalaraj, "Big data analytics in supply chain management: A systematic literature review and research directions," *Big Data Cognit. Comput.*, vol. 6, no. 1, p. 17, Feb. 2022.
[37] J. Xu, M. E. P. Pero, F. Ciccullo, and A. Sianesi, "On relating big data analytics to supply chain planning: Towards a research agenda," *Int. J. Phys. Distrib. Logistics Manage.*, vol. 51, no. 6, pp. 656–682, Jul. 2021, doi: 10.1108/IJPDLM-04-2020-0129.
[38] M. Núñez-Merino, J. M. Maqueira-Marín, J. Moyano-Fuentes, and P. J. Martínez-Jurado, "Information and digital technologies of industry 4.0 and lean supply chain management: A systematic literature review," *Int. J. Prod. Res.*, vol. 58, no. 16, pp. 5034–5061, Aug. 2020.
[39] N. Jahani, A. Sepehri, H. R. Vandchali, and E. B. Tirkolaee, "Application of industry 4.0 in the procurement processes of supply chains: A systematic literature review," *Sustainability*, vol. 13, no. 14, p. 7520, Jul. 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/14/7520
[40] C. Bălan, "The disruptive impact of future advanced ICTs on maritime transport: A systematic review," *Supply Chain Manage., Int. J.*, vol. 25, no. 2, pp. 157–175, Dec. 2018, doi: 10.1108/SCM-03-2018-0133.
[41] A. Lagorio, G. Zenezini, G. Mangano, and R. Pinto, "A systematic literature review of innovative technologies adopted in logistics management," *Int. J. Logistics Res. Appl.*, pp. 1–24, Nov. 2020, doi: 10.1080/13675567.2020.1850661.
[42] M. M. Queiroz, R. Telles, and S. H. Bonilla, "Blockchain and supply chain management integration: A systematic review of the literature," *Supply Chain Manage., Int. J.*, vol. 25, no. 2, pp. 241–254, Aug. 2019, doi: 10.1108/SCM-03-2018-0143.
[43] Y. Riahi, T. Saikouk, A. Gunasekaran, and I. Badraoui, "Artificial intelligence applications in supply chain: A descriptive bibliometric analysis and future research directions," *Expert Syst. Appl.*, vol. 173, Jul. 2021, Art. no. 114702, doi: 10.1016/j.eswa.2021.114702.
[44] H. Fatorachian and H. Kazemi, "Impact of industry 4.0 on supply chain performance," *Prod. Planning Control*, vol. 32, no. 1, pp. 63–81, Jan. 2020.
[45] C. Chauhan and A. Singh, "A review of industry 4.0 in supply chain management studies," *J. Manuf. Technol. Manage.*, vol. 31, no. 5, pp. 863–886, Nov. 2019, doi: 10.1108/JMTM-04-2018-0105.
[46] M. Koot, M. R. K. Mes, and M. E. Iacob, "A systematic literature review of supply chain decision making supported by the Internet of Things and big data analytics," *Comput. Ind. Eng.*, vol. 154, Apr. 2021, Art. no. 107076, doi: 10.1016/j.cie.2020.107076.
[47] R. Toorajipour, V. Sohrabpour, A. Nazarpour, P. Oghazi, and M. Fischl, "Artificial intelligence in supply chain management: A systematic literature review," *J. Bus. Res.*, vol. 122, pp. 502–517, Jan. 2021.
[48] H. Younis, B. Sundarakani, and M. Alsharairi, "Applications of artificial intelligence and machine learning within supply chains: Systematic review and future research directions," *J. Model. Manage.*, Aug. 2021, doi: 10.1108/JM2-12-2020-0322.
[49] M. Akbari and T. N. A. Do, "A systematic review of machine learning in logistics and supply chain management: Current trends and future directions," *Benchmarking, Int. J.*, vol. 28, no. 10, pp. 2977–3005, Mar. 2021, doi: 10.1108/BIJ-10-2020-0514.
[50] S. Gupta, S. Modgil, S. Bhattacharyya, and I. Bose, "Artificial intelligence for decision support systems in the field of operations research: Review and future scope of research," *Ann. Oper. Res.*, vol. 308, nos. 1–2, pp. 215–274, Jan. 2021, doi: 10.1007/s10479-020-03856-6.
[51] A. Khakpour, R. Colomo-Palacios, and A. Martini, "Visual analytics for decision support: A supply chain perspective," *IEEE Access*, vol. 9, pp. 81326–81344, 2021, [Online]. Available: https://ieeexplore.ieee.org/document/9445829/

[52] M. Woschank, E. Rauch, and H. Zsifkovits, ''A review of further directions for artificial intelligence, machine learning, and deep learning in smart logistics,'' *Sustainability*, vol. 12, no. 9, p. 3760, May 2020. [Online]. Available: https://www.mdpi.com/2071-1050/12/9/3760

[53] U. Bodkhe, S. Tanwar, K. Parekh, P. Khanpara, S. Tyagi, N. Kumar, and M. Alazab, ''Blockchain for industry 4.0: A comprehensive review,'' *IEEE Access*, vol. 8, pp. 79764–79800, 2020. [Online]. Available: https://ieeexplore.ieee.org/document/9069885/

[54] F. Ciampi, G. Marzi, S. Demi, and M. Faraoni, ''The big data-business strategy interconnection: A grand challenge for knowledge management. A review and future perspectives,'' *J. Knowl. Manage.*, vol. 24, no. 5, pp. 1157–1176, Jun. 2020, doi: 10.1108/JKM-02-2020-0156.

[55] P.-L. Sanchez-Gonzalez, D. Díaz-Gutiérrez, T. Leo, and L. Núñez-Rivas, ''Toward digitalization of maritime transport?'' *Sensors*, vol. 19, no. 4, p. 926, Feb. 2019. [Online]. Available: http://www.mdpi.com/1424-8220/19/4/926

[56] D. T. Nguyen, Y. Adulyasak, J.-F. Cordeau, and S. I. Ponce, ''Data-driven operations and supply chain management: Established research clusters from 2000 to early 2020,'' *Int. J. Prod. Res.*, pp. 1–25, Jul. 2021, doi: 10.1080/00207543.2021.1956695.

[57] K. Lamba and S. P. Singh, ''Big data in operations and supply chain management: Current trends and future perspectives,'' *Prod. Planning Control*, vol. 28, nos. 11–12, pp. 877–890, Sep. 2017, doi: 10.1080/09537287.2017.1336787.

[58] S. Talwar, P. Kaur, S. F. Wamba, and A. Dhir, ''Big data in operations and supply chain management: A systematic literature review and future research agenda,'' *Int. J. Prod. Res.*, vol. 59, no. 11, pp. 3509–3534, Jun. 2021, doi: 10.1080/00207543.2020.1868599

[59] M. Fruth and F. Teuteberg, ''Digitization in maritime logistics—What is there and what is missing?'' *Cogent Bus. Manage.*, vol. 4, no. 1, pp. 1–40, Nov. 2017, doi: 10.1080/23311975.2017.1411066.

[60] R. M. L. Rebelo, S. C. F. Pereira, and M. M. Queiroz, ''The interplay between the Internet of Things and supply chain management: Challenges and opportunities based on a systematic literature review,'' *Benchmarking, Int. J.*, vol. 29, no. 2, pp. 683–711, Jun. 2021, doi: 10.1108/BIJ-02-2021-0085.

[61] H. Birkel and J. M. Müller, ''Potentials of industry 4.0 for supply chain management within the triple bottom line of sustainability—A systematic literature review,'' *J. Cleaner Prod.*, vol. 289, Mar. 2021, Art. no. 125612, doi: 10.1016/j.jclepro.2020.125612.

[62] Y. Lu, S. Papagiannidis, and E. Alamanos, ''Internet of Things: A systematic review of the business literature from the user and organisational perspectives,'' *Technol. Forecasting Social Change*, vol. 136, pp. 285–297, Nov. 2018, doi: 10.1016/j.techfore.2018.01.022.

[63] M. Ben-Daya, E. Hassini, and Z. Bahroun, ''Internet of Things and supply chain management: A literature review,'' *Int. J. Prod. Res.*, vol. 57, nos. 15–16, pp. 4719–4742, Aug. 2019, doi: 10.1080/00207543.2017.1402140.

[64] M. Vivaldini and P. R. de Sousa, ''Blockchain connectivity inhibitors: Weaknesses affecting supply chain interaction and resilience,'' *Benchmarking, Int. J.*, vol. 28, no. 10, pp. 3102–3136, Apr. 2021, doi: 10.1108/BIJ-10-2020-0510.

[65] A. Z. Abideen, J. Pyeman, V. P. K. Sundram, M.-L. Tseng, and S. Sorooshian, ''Leveraging capabilities of technology into a circular supply chain to build circular business models: A state-of-the-art systematic review,'' *Sustainability*, vol. 13, no. 16, p. 8997, Aug. 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/16/8997

[66] G. F. Frederico, J. A. Garza-Reyes, A. Anosike, and V. Kumar, ''Supply chain 4.0: Concepts, maturity and research agenda,'' *Supply Chain Manage., Int. J.*, vol. 25, no. 2, pp. 262–282, Sep. 2019.

[67] S. S. Kamble, A. Gunasekaran, and S. A. Gawankar, ''Sustainable industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives,'' *Process Saf. Environ. Prot.*, vol. 117, pp. 408–425, Jul. 2018, doi: 10.1016/j.psep.2018.05.009.

[68] H. S. Birkel and E. Hartmann, ''Impact of IoT challenges and risks for SCM,'' *Supply Chain Manage., Int. J.*, vol. 24, no. 1, pp. 39–61, Jan. 2019, doi: 10.1108/SCM-03-2018-0142.

[69] S. Pan, D. Trentesaux, E. Ballot, and G. Q. Huang, ''Horizontal collaborative transport: Survey of solutions and practical implementation issues,'' *Int. J. Prod. Res.*, vol. 57, nos. 15–16, pp. 5340–5361, Aug. 2019, doi: 10.1080/00207543.2019.1574040.

[70] C. Dong, A. Akram, D. Andersson, P.-O. Arnäs, and G. Stefansson, ''The impact of emerging and disruptive technologies on freight transportation in the digital era: Current state and future trends,'' *Int. J. Logistics Manage.*, vol. 32, no. 2, pp. 386–412, Apr. 2021, doi: 10.1108/IJLM-01-2020-0043.

[71] A. Rejeb, K. Rejeb, S. J. Simske, and H. Treiblmaier, ''Drones for supply chain management and logistics: A review and research agenda,'' *Int. J. Logistics Res. Appl.*, pp. 1–24, Sep. 2021, doi: 10.1080/13675567.2021.1981273.

[72] V. Varriale, A. Cammarano, F. Michelino, and M. Caputo, ''New organizational changes with blockchain: A focus on the supply chain,'' *J. Organizational Change Manage.*, vol. 34, no. 2, pp. 420–438, Mar. 2021, doi: 10.1108/JOCM-08-2020-0249.

[73] P. T.-W. Lee, Q. Zhang, K. Suthiwartnarueput, D. Zhang, and Z. Yang, ''Research trends in belt and road initiative studies on logistics, supply chains, and transportation sector,'' *Int. J. Logistics Res. Appl.*, vol. 23, no. 6, pp. 525–543, Nov. 2020, doi: 10.1080/13675567.2020.1828318.

[74] I. Ambrasaite, M. B. Barfod, and K. B. Salling, ''MCDA and risk analysis in transport infrastructure appraisals: The Rail Baltica case,'' *Proc.-Social Behav. Sci.*, vol. 20, pp. 944–953, Jan. 2011.

[75] M. Thürer, I. Tomašević, M. Stevenson, C. Blome, S. Melnyk, H. K. Chan, and G. Q. Huang, ''A systematic review of China's belt and road initiative: Implications for global supply chain anagement,'' *Int. J. Prod. Res.*, vol. 58, no. 8, pp. 2436–2453, Apr. 2020, doi: 10.1080/00207543.2019.1605225.

[76] M. Kunovjanek, N. Knofius, and G. Reiner, ''Additive manufacturing and supply chains—A systematic review,'' *Prod. Planning Control*, pp. 1–21, Dec. 2020, doi: 10.1080/09537287.2020.1857874.

[77] R. D. Raut, A. Gotmare, B. E. Narkhede, U. H. Govindarajan, and S. U. Bokade, ''Enabling technologies for industry 4.0 manufacturing and supply chain: Concepts, current status, and adoption challenges,'' *IEEE Eng. Manag. Rev.*, vol. 48, no. 2, pp. 83–102, Jun. 2020. [Online]. Available: https://ieeexplore.ieee.org/document/9069488/

[78] C. J. C. Jabbour, P. D. C. Fiorini, N. O. Ndubisi, M. M. Queiroz, and É. L. Piato, ''Digitally-enabled sustainable supply chains in the 21st century: A review and a research agenda,'' *Sci. Total Environ.*, vol. 725, Jul. 2020, Art. no. 138177, doi: 10.1016/j.scitotenv.2020.138177.

[79] S. Tiwari, ''Supply chain integration and industry 4.0: A systematic literature review,'' *Benchmarking, Int. J.*, vol. 28, no. 3, pp. 990–1030, Nov. 2020, doi: 10.1108/BIJ-08-2020-0428.

[80] R. Meriton, R. Bhandal, G. Graham, and A. Brown, ''An examination of the generative mechanisms of value in big data-enabled supply chain management research,'' *Int. J. Prod. Res.*, vol. 59, no. 23, pp. 7283–7310, Nov. 2020, doi: 10.1080/00207543.2020.1832273.

[81] A.-D.-M. Agamez-Arias and J. Moyano-Fuentes, ''Intermodal transport in freight distribution: A literature review,'' *Transp. Rev.*, vol. 37, no. 6, pp. 782–807, Nov. 2017, doi: 10.1080/01441647.2017.1297868.

[82] S. Kummer, D. M. Herold, M. Dobrovnik, J. Mikl, and N. Schäfer, ''A systematic review of blockchain literature in logistics and supply chain management: Identifying research questions and future directions,'' *Future Internet*, vol. 12, no. 3, p. 60, Mar. 2020. [Online]. Available: https://www.mdpi.com/1999-5903/12/3/60

[83] A. A. A. Khanfar, M. Iranmanesh, M. Ghobakhloo, M. G. Senali, and M. Fathi, ''Applications of blockchain technology in sustainable manufacturing and supply chain management: A systematic review,'' *Sustainability*, vol. 13, no. 14, p. 7870, Jul. 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/14/7870

[84] P. K. Wan, L. Huang, and H. Holtskog, ''Blockchain-enabled information sharing within a supply chain: A systematic literature review,'' *IEEE Access*, vol. 8, pp. 49645–49656, 2020. [Online]. Available: https://ieeexplore.ieee.org/document/9032112/

[85] Y. Wang, J. H. Han, and P. Beynon-Davies, ''Understanding blockchain technology for future supply chains: A systematic literature review and research agenda,'' *Supply Chain Manage.*, vol. 24, no. 1, pp. 62–84, Jan. 2019, doi: 10.1108/SCM-03-2018-0148.

[86] I. Taboada and H. Shee, ''Understanding 5G technology for future supply chain management,'' *Int. J. Logistics Res. Appl.*, vol. 24, no. 4, pp. 392–406, May 2020, doi: 10.1080/13675567.2020.1762850.

[87] I. Mistry, S. Tanwar, S. Tyagi, and N. Kumar, ''Blockchain for 5G-enabled IoT for industrial automation: A systematic review, solutions, and challenges,'' *Mech. Syst. Signal Process.*, vol. 135, Jan. 2020, Art. no. 106382, doi: 10.1016/j.ymssp.2019.106382.

[88] V. Paliwal, S. Chandra, and S. Sharma, "Blockchain technology for sustainable supply chain management: A systematic literature review and a classification framework," *Sustainability*, vol. 12, no. 18, p. 7638, Sep. 2020. [Online]. Available: https://www.mdpi.com/2071-1050/12/18/7638
[89] M. Schroeder and S. Lodemann, "A systematic investigation of the integration of machine learning into supply chain risk management," *Logistics*, vol. 5, no. 3, p. 62, Sep. 2021. [Online]. Available: https://www.mdpi.com/2305-6290/5/3/62
[90] A. Park and H. Li, "The effect of blockchain technology on supply chain sustainability performances," *Sustainability*, vol. 13, no. 4, p. 1726, Feb. 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/4/1726
[91] S. E. Chang and Y. Chen, "When blockchain meets supply chain: A systematic literature review on current development and potential applications," *IEEE Access*, vol. 8, pp. 62478–62494, 2020. [Online]. Available: https://ieeexplore.ieee.org/document/9047881/
[92] N. Upadhyay, "Demystifying blockchain: A critical analysis of challenges, applications and opportunities," *Int. J. Inf. Manage.*, vol. 54, Oct. 2020, Art. no. 102120, doi: 10.1016/j.ijinfomgt.2020.102120.
[93] H. Treiblmaier, "The impact of the blockchain on the supply chain: A theory-based research framework and a call for action," *Supply Chain Manage., Int. J.*, vol. 23, no. 6, pp. 545–559, Sep. 2018, doi: 10.1108/SCM-01-2018-0029.
[94] A. Batwa and A. Norrman, "Blockchain technology and trust in supply chain management: A literature review and research agenda," *Oper. Supply Chain Manage., Int. J.*, vol. 14, no. 2, pp. 203–220, Jan. 2021. [Online]. Available: https://journal.oscm-forum.org/publication/article/blockchain-technology-and-trust-in-supply-chain-managementa-literature-review-and-research-agenda
[95] N. Etemadi, Y. Borbon-Galvez, F. Strozzi, and T. Etemadi, "Supply chain disruption risk management with blockchain: A dynamic literature review," *Information*, vol. 12, no. 2, p. 70, Feb. 2021. [Online]. Available: https://www.mdpi.com/2078-2489/12/2/70
[96] C. Wan, Z. Yang, D. Zhang, X. Yan, and S. Fan, "Resilience in transportation systems: A systematic review and future directions," *Transp. Rev.*, vol. 38, no. 4, pp. 479–498, Jul. 2018, doi: 10.1080/01441647.2017.1383532.
[97] V. Varriale, A. Cammarano, F. Michelino, and M. Caputo, "The unknown potential of blockchain for sustainable supply chains," *Sustainability*, vol. 12, no. 22, p. 9400, Nov. 2020. [Online]. Available: https://www.mdpi.com/2071-1050/12/22/9400
[98] A. Batta, M. Gandhi, A. K. Kar, N. Loganayagam, and V. Ilavarasan, "Diffusion of blockchain in logistics and transportation industry: An analysis through the synthesis of academic and trade literature," *J. Sci. Technol. Policy Manage.*, vol. 12, no. 3, pp. 378–398, Jul. 2021, doi: 10.1108/JSTPM-07-2020-0105.
[99] A. Felsberger and G. Reiner, "Sustainable industry 4.0 in production and operations management: A systematic literature review," *Sustainability*, vol. 12, no. 19, p. 7982, Sep. 2020. [Online]. Available: https://www.mdpi.com/2071-1050/12/19/7982
[100] M. H. Naseem and J. Yang, "Role of industry 4.0 in supply chains sustainability: A systematic literature review," *Sustainability*, vol. 13, no. 17, p. 9544, Aug. 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/17/9544

DAVID L. CORTÉS-MURCIA received the B.Sc. and M.Sc. degrees in industrial engineering from the Escuela Colombiana de Ingeniería Julio Garavito, Colombia, and the Ph.D. degree in optimization and systems reliability from the Université de Technologie de Troyes, France. He is currently a Postdoctoral Fellow with the Research Group of Logistics Systems, Faculty of Engineering, Universidad de La Sabana, Colombia. His research includes studies in sustainable logistics, routing with electric vehicles, optimization, and simulation in Colombia and France. His research interests include supply chain design, green logistics, and operations research.

WILLIAM J. GUERRERO received the B.Sc. and M.Sc. degrees in industrial engineering and the Ph.D. degree in engineering from the Universidad de Los Andes, Colombia, and the Ph.D. degree in optimization and systems reliability from the Université de Technologie de Troyes, France. He is currently an Associate Professor and the Head of the Research Group of Logistic Systems, Faculty of Engineering, Universidad de La Sabana, Colombia. His research includes studies in healthcare logistics, data analytics, optimization, and simulation in Colombia and France. His research interests include transportation systems and operations research.

JAIRO R. MONTOYA-TORRES received the Ph.D. degree in industrial engineering from the Ecole des Mines de Saint-Etienne and the Habilitation à Diriger des Recherches degree in logistics and operational research from INSA Lyon, for the accreditation for research supervision. He is currently a Full Professor and the Director of the Ph.D. program in logistics and supply chain management and the Ph.D. program in engineering with the School of Engineering, Universidad de La Sabana, Chia, Colombia. His research interests include logistics and quantitative modeling, particularly interested in the resolution of complex, realistic decision-making problems at strategic, tactical, operational levels in the areas of reverse and sustainable logistics, supply chain management, urban/city logistics, distribution, operations, and scheduling in manufacturing and services. For more information, visit his personal website (https://jrmontoya.wordpress.com/).